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DRAWING THE RED LINE: COST BENEFIT ANALYSIS ON LARGE LIFE RAFTS

GRADUATE RESEARCH PAPER

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Abstract

The tightening Department of Defense budget necessitates cutting costs within all subordinate organizations, including Air Mobility Command (AMC). As the budget becomes more constrained, AMC will need to fly fewer missions or find new ways to reduce its operating expenses. Due to the rising cost of fuel and the high volume of flights across AMC aircraft, the portion of the budget spent on fuel is an obvious area of focus for cost-reduction. Within the last 5 years, AMC has set up a Fuel-Efficiency Office (FEO) in order to analyze costs and make decisions that will save money on operational expenses related to fuel. The basic tenet is that the Air Force reduces the cost of flying by removing extra onboard equipment because lowering the weight of the aircraft reduces the amount of jet fuel that an aircraft burns.

Often times, onboard safety equipment is overlooked when considering weight-reduction strategies because these items are perceived to be essential for saving lives or reducing casualties in the event of an emergency. However, some legacy items may no longer be necessary or even practical because circumstances have changed; thereby diminishing their usefulness. Therefore, reevaluating past decisions regarding safety equipment could uncover opportunities for cuts.

The focus of this paper is to analyze the need for large life rafts on the C-5, C-17, C-130, KC-10 and KC-135. Carrying life rafts aboard these aircraft adds considerable weight to each flight which, in turn, requires additional fuel. Transporting the life rafts adds about 1000-pounds aboard nearly 100,000 annual AMC flights and costs over $7,000,000 for fuel alone. Not only does AMC incur higher fuel costs, the organization must also provide funding for procurement, training, maintenance, and storage for these rafts. Ironically, many of the original reasons for

having these life rafts aboard each plane have been altered or mitigated over the years due to improved technologies and the change of mission for these aircraft, yet the decision to carry these life rafts has rarely been re-evaluated.

As budgets become more constrained, units may be forced to either curtail safety or reduce mission capability. In the near future, leaders may have to make difficult decisions that challenge existing decision-making paradigms regarding safety issues to discern if items such as life rafts actually increase safety, or if they merely increase the perception of safety. Critically evaluating the usefulness of safety items aboard aircraft could not only uncover unnecessary expenses, but could also reveal opportunities for the development of more effective and light-weight solutions. While procurement, maintenance, training, and ferrying costs of life rafts comprise a small percentage of AMC's overall budget, this analysis is noteworthy because it reveals some significant, but less obvious nuances of decision-making when perceived safety is involved.

This paper is dedicated to those who have served and continue to serve in our Armed Forces. My admiration for those that have and continue to sacrifice their freedom in order to provide freedom for others grows every day. To you, I salute.

Acknowledgements

I sincerely appreciate the guidance, help and teaching that I have received from Dr. Heminger during this study. His vast knowledge of the Delphi Study and general wisdom pulled me out from the weeds on many occasions to once again see the forest.

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Colonel Fowler, thank you sir for your direction, wisdom, and insightfulness on this study. Your coordination and help was of great value and hope that I have delivered a product that will be of use for AMC and the FEO office.

I want to specifically thank Chuck Stiles for his amazing help in this research project. Your ability to continually deliver amazed me! I have the greatest respect.

Don Anderson, sir I want to say thank you for your help in collecting and providing me vast amounts of data in a minutes notice. I would not have been able to accomplish any of the tasks without it.

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Your thoughts, vision, and leadership are instrumental the Airmen of our United States Air Force.

Lastly, I want to thank my wife for her love, kindness, generosity, wisdom, and most of all programing skills that helped create the KML database to depict the near 400,000 flights. You saved me at least three years of time, and I will be in your debt!

Contents

Table of Figures

I. Introduction

> *"As we look to our military's posture and budget, we recognize that our country is still reeling from a grave and global economic downturn and is maintaining nearly historic fiscal deficits and national debt. Indeed, I believe that our debt is the greatest threat to our national security. If we as a country do not address our fiscal imbalances in the near-term, our national power will erode, and the costs to our ability to maintain and sustain influence could be great. To do its part, the Defense Department must and will become more efficient and disciplined, while improving our effectiveness. We must carefully and deliberately balance the imperatives of a constrained budget environment with the requirements we place on our military in sustaining and enhancing our security.*
>
> *Going forward our fundamental resourcing problem will be identifying where we can reduce spending while minimizing the additional risk we will have to take on. For too much of the past decade we have not been forced to be disciplined with our choices. This must change, and it already has. We have identified a number of efficiencies in our budget and have reduced spending, while also retaining the combat readiness, force structure, essential modernization, and personnel programs we need. We are proud of what we have done so far, identifying $100 billion in efficiency savings over the next five years. But we need to do more."*
>
> *-Admiral Michael G. Mullen, Chairman of the Joint Chiefs of Staff*

Background of Problem/Situation

Fuel consumption has become a major focal point for the Department of Defense (DoD) due to mounting budget constraints (Figure 1). The Air Force must enhance its shrewdness when deciding how to fulfill missions. A substantial portion of the Air Force budget is allocated to purchasing fuel**.** In 2011, the Air Force used over 2.4 billion gallons of fuel in which 1.536 billion gallons were used on large mobility aircraft costing 8.83 billion dollars. (Starosta, July 2012).

USAF Fuel Purchases

Fiscal Year	Dollars (In Billions)
2006	$5.99
2007	$5.93
2008	$8.18
2009	$5.63
2010	$7.30
2011	$8.83
TOTAL (2006-2011)	$41.87

Fiscal Year	$ Per Gallon
2006	2.24
2007	2.24
2008	3.17
2009	2.16
2010	2.73
2011	3.40
2012 (Oct to March)	3.93

Figure 1. USAF Fuel Purchases 2006-2012: (Gabe, 2012)

General Faykes, Deputy Assistant Secretary for Budget, stated that every $10 increase per barrel of crude oil costs the Air Force about $600 million per annum (Lopez, 2008). Calculated as such, this means that the increase cost to the Air Force has been nearly $2 billion annually on average and continues to rise at an alarming rate. The Department of Defense (DoD) has reacted to the increased fuel costs by cutting 40,000 Air Force jobs; however, this savings has summed to only $8 billion (Springer, 2007). Contrary to the increase in fuel costs, which have shown to be unlimited, the reactionary attempt to balance the budget by eliminating jobs is short-sighted, as there are only so many positions that can be cut before compromising the effectiveness of the military force. A more appropriate response to escalating fuel costs would be a strategy to reduce the amount of fuel used; thereby directly correlating the savings with the consumption. Long-term fuel savings can be achieved through the replacement of older, less efficient engines with newer, more economical replacements. However, such changes require research, engineering, testing, and aircraft restructuring – all which require a substantial amount of time and upfront capital investment. In the meantime, a more immediate and less extensive approach should be considered: reducing the weight of an aircraft, which can be used to directly save the Air Force money on fuel.

The Air Force aircraft often carries equipment on board that is rarely used and may be removed without major consequence. Large life rafts are one such example – as water landings and aircraft ditches occur so infrequently. However, their utility in the unlikely event of an emergency is largely unknown and immeasurable. In this study, we will weigh both the cost-savings and ramifications of removing large life rafts.

Air Force regulations require all heavy aircraft to carry safety equipment on board for emergency purposes that comply with the FAA rules. For missions that extend 50 miles or more past land and carry passengers, aircraft must be equipped with life rafts and other emergency equipment (FAA, 2013). Although large mobility aircraft do not need to have this equipment on every flight, the costs are too great to remove and reinstall for any given flight. Taken in total, these items are sizable and add tremendous weight to the aircraft, often up to 1,000 pounds per aircraft.

While the benefit of these emergency items can be readily appreciated, one must question what purpose a life raft serves for local missions conducted over land. Furthermore, the survivability of large life rafts after water impact is very low and does not provide the intended service to the crew and passengers.

Carrying life-support equipment adds procurement, maintenance, training, manpower, and ferrying costs. Initial training, training support structure, quarterly maintenance, lost opportunities and additional manpower are some of the additional indirect costs associated with carrying secondary equipment on-board aircraft.

This paper analyzes if the Air Force should ever remove life rafts by answering these three questions: 1) Are life rafts effective on the C-5, C-17, C-130, KC-10, and KC-135? 2) How

much would be saved by removing life rafts? 3) What are the implicated risks of either removing or keeping life rafts on these aircraft?

Research Question

The research study question thus follows:

1) What is the rationale to carry large life rafts on the C-5, C-17, C-130, KC-10 and KC-135 and should the policy change based upon a risk assessment of ditching/water impact occurrence, life raft capability, and total cost?

Related Problems

A. Do the costs (ferrying fuel, procurement, maintenance, training and infrastructure) of large life rafts on the C-130, C-17, KC-10, C-5 and KC-135 outweigh the reallocation of those funds?
B. Do the policies of carrying large life rafts on the aircraft provide the safety to our Airmen that we deem critical?
C. Have the aircraft in the Air Force become so reliable that it has surpassed the policy to carry large life rafts on these aircraft?
D. If large life rafts were removed from aircraft, what would be the political impact?

Research Objective and Focus

Procurement of new aircraft has been delayed or canceled; airmen have been released from duty, and entire systems throughout the Air Force have been eliminated or scaled back because of a decreasing budget. In the upcoming decades, we will continue to see a shrinking budget, and the Air Force will have to not only make smart decisions to continue operating in a fiscally constrained environment but also cut more systems, airmen, and aviation platforms. The 2012-initiated Sequestration has resulted in cuts to many programs in the military and it is very likely that this is just the beginning of reductions to come.

Escalating fuel costs are causing the U.S. Air Force to re-evaluate the way in which it conducts business. Since both drag and weight impact the amount of thrust needed to fly an

aircraft, they directly affect fuel consumption. Therefore, alleviating drag or weight of an aircraft will logically reduce the amount of fuel needed to perform a mission, and more importantly, will reduce the funding required for each flight.

Each piece of equipment carried aboard the aircraft - such as life rafts - provide a certain capability for our force but also increases the weight of the plane. This research paper will focus on a cost-benefit analysis for the Air Force's Major Weapons Systems that include the C-5, C-17, C-130, KC-10, and KC-135 to determine the point at which the cost of carrying large life rafts outweigh the benefit. This study will analyze the flight risk of each aircraft by showing the percent of flights that fly with passengers over large bodies of water. In addition, this study will discuss the opinions of experts in the industry regarding the importance of large life rafts. In all, this study will improve the knowledge by examining the need to carry large life rafts and recognizing the non-financial considerations for this type of decision.

Methodology

The research focus is directly linked to the life-support equipment on board the C-5, C-17, C-130, KC-10, and KC-135 aircraft, and more specifically, the large life rafts. The cost and necessity for life rafts is examined, providing the foundation for the cost-benefit analysis. In addition, a Delphi study is conducted, which includes senior leadership in AMC, FAA, ICAO and commercial airline personnel on the subject. The study is centered on the utility, cost, public perception, and risk assessment for life rafts, thereby providing analysis for the rare event of ditching and use of large life rafts in such circumstances.

Federal Aviation Administration (FAA), International Civil Aviation Organization (ICAO), Air Mobility Command (AMC), and commercial airlines all play critical roles in

determining the regulations governing oceanic travel. During the Delphi study, information regarding the rationale for large life rafts and their overall purpose is examined. The subject matter experts (SMEs) received three-rounds of questions examining their perspectives on the use of large life rafts on these airframes.

In addition to the Delphi Study, an analysis of the aircraft risk of water impact and the cost of ferrying the equipment is conducted by analyzing flights for these aircraft during the period of 2009 to 2013.

Implications

The C-5, C-17, C-130, KC-10, and KC-135 are the major airlift and air refueling platforms for Air Mobility Command (AMC). The DoD has procured 1,653 of these aircraft and in 2013 they are expected to fly close to 500,000 hours (Fact Sheet C-5, KC-10, C-17, C-130, KC-135, 2011).

The Fuel Efficiency Office (FEO), at AMC, has run numerous initiatives to reduce the weight and increase the efficiency of aircraft while also training crews on fuel conservation through flight operations. The FEO has realized millions of dollars in savings through their efforts.

Aircrews go through extensive training on ditching, using life rafts and surviving in the water. There is a large cost for this capability. The extra fuel needed on daily flights, the training of personnel, the procurement, and the maintenance of the equipment are some of the costs to ensure that life rafts are useful to aircrew and passengers.

Analogous to life rafts, parachutes are also onboard safety equipment that adds weight to the aircraft for the intended purpose of saving lives. AMC decided to remove parachutes from

these aircraft because they are not mandated by the FAA, and the cost outweighed the benefit. Ironically, there are many times bailing out of an aircraft is a better option than ditching and is ultimately a cheaper alternative to provide. The decision has also been made to remove large life rafts for some circumstances. Specifically, the KC-135 was able to remove large life rafts on flights not over water because the life rafts could be easily removed. If AMC did remove the life rafts from the C-5, C-17, C-130, KC-10, and KC-135 permanently, the savings may allow for money to be spent on aircraft features that ultimately improve the safety more for passengers and the crew.

This study examines this point and tries to better understand why life rafts are rarely part of the weight-reduction discussion for aircraft.

This research paper focus is on a cost-benefit analysis for the Air Force's Major Weapons Systems that include the C-5, C-17, C-130, KC-10, and KC-135 to establish the point at which the additional cost of carrying large life rafts outweigh their benefit. This study enhances the knowledge regarding life rafts and their true value.

In summary, this research utilizes a Delphi study to understand the qualitative issues such as the morale and leadership implications to the removal of life rafts. A risk analysis is used to understand the quantitative aspect regarding the savings and probability of ditching and successful employment of large life rafts on the C-5, C-17, C-130, KC-10, and KC-135 aircraft. The next section reviews the historical aspect of life rafts, and rationale for employment on any large aircraft. The methodology section follows the literature review, and delivers the Delphi approach and analysis technique. Results and analysis will thus follow, illustrating the main points and providing the data for the conclusions.

Figure 2. 20-Man Life Raft

Source: http://upload.wikimedia.org/wikipedia/commons/d/d6/Life_raft.jpg

II. Literature Review

This paper is broken into six main sections: (1) The history of life rafts including the initial use and regulations that soon followed; (2) The definitions and rules that govern the use of life rafts, (3) Life rafts and their importance as a safety feature (4) A review on civilian airline crashes and the use of life rafts to provides a commercial comparison (5) An investigation on the C-5, C-17, C-130, KC-10, and KC-135 ditching characteristics, life raft employment, and crash analysis; and lastly (6) The literature review will contain a section on the importance of a Delphi study and a further analysis on life rafts and flights.

Historical Perspective on Life Rafts and Regulations

In 1934 during a routine exercise flight, a navy plane crashed into the ocean, and unfortunately, the pilot perished in the water (Patten, 2013). The post-investigation revealed that a floatation device may have saved his life, which initiated the first call for flotation devices on-board aircraft. In 1939, the first one-man life raft was adopted by navy aviation and soon after, larger bomber aircraft began using seven-man life rafts (Patten, 2013).

In the next decade, numerous aviation crashes occurred in the Pacific in which life rafts saved the crew on board. Incredible survival stories came about during this period and there are two, in particular, that illustrate the importance of life rafts in military aviation. The first story details the 46-day survival of 2 of the 11 crew members from the B-24D "Green Hornet" on a life raft after their plane crashed into the Pacific Ocean during a reconnaissance mission (Forbes, 1997). The second story details the events of a B-17 crash with Eddie Rickenbacker and six crew members who utilized three rubber life rafts, surviving at sea for 24 days before finally reaching land and radioing help (Rea, 2004).

The “Green Hornet” crashed into the ocean while having mechanical issues and it killed 8 of the 11 aircrew (Forbes, 1997). The three survivors were able to employ a large life raft and survive at sea eating fish and drinking rain water (Forbes, 1997). Unfortunately one of the members died after 37 days at sea and the others were captured by the Japanese Navy on the 47th day (Forbes, 1997). One member did survive to tell his amazing story, and to reinforce that life rafts are truly life-savers.

The B-17 ditched into the ocean in 1942 after straying off course and engines seizing because of fuel starvation (Rea, 2004). The crew survived for 24 days on life rafts by drinking the rain-water and eating fish (Rea, 2004). On the last day, they were spotted by rescue operations and brought home to tell another heroic story (Rea, 2004).

This era was instrumental in laying the foundation for aviation safety. Life rafts proved their worth over and over again. Today life rafts are part of regulatory code because of these many success stories. In terms of technologically, life rafts have not changed that much over time, but their utility-rate has, due to aircraft reliability and the mission. This next section provides a better understanding of ditching versus inadvertent water impact and the regulations' governing aircraft.

The Federal Aviation Administration (FAA) is the regulatory agency that sets policy and procedures with the International Civil Aeronautical Organization (ICAO) for aircraft safety. The FAA originated in 1926 under the Commerce Act of 1926 and wrote into law that all U.S. air carriers flying greater than 50 miles from shore are required to carry life rafts (History Origins, 1996). Aircraft that carry more than 20 passengers or cargo load of greater than 6,000 pounds fall under FAA Parts 121, 125 and 135, which requires the aircraft to be equipped with life rafts (Figure 3) (FAA, 2012).

The aircraft must have at least two life rafts and if the largest of the life rafts were to be damaged then the remaining life raft(s) would have to carry all the passengers based on the life rafts over-capacity rating (FAA, 2012). In addition to the life rafts, there is a survival kit for each life raft that is attached via a lanyard, and the survival kit must carry the required items by the FAA (FAA, 2012).

Table 1 – FAA Required Emergency and Survival Equipment for Overwater Operations.

Type of Operation		Overwater Operations					
Operating Under FAA FAR…	Description of Operation	0-50 Miles		Extended Overwater Operations {8}			
				> 50 to 100 Miles		> 100 Miles	
		Required Equipment	Required per FAR…	Required Equipment	Required per FAR…	Required Equipment	Required per FAR…
Part 121	Airlines	First Aid Kit {11} Flotation Device {1}	121.309(d) 121.340(a)	First Aid Kit {11} Life Preserver {2} Life Raft {4} ELT	121.309(d) 121.339(a)(1) 121.339(a)(2) 121.339(a)(4)	First Aid Kit {11} Life Preserver {2} Life Raft {4} ELT	121.309(d) 121.339(a)(1) 121.339(a)(2) 121.339(a)(4)

Notes for Table 1:

{1} An "approved flotation means" is required for each occupant of the aircraft. This may be an individual flotation device approved under FAA TSO-C72b or C72c which can be an inflatable type {EAM Model GA-12 for example} or non-inflatable type {seat cushion}.

{2} An approved life preserver equipped with a survivor locator light for each occupant of the aircraft. Life preservers are approved under FAA TSO-C13d, C13e, and C13f. Locator lights are approved under TSO-C85 or C85a.

{3} Approved life raft{s} of a rated capacity to accommodate all the occupants of the aircraft. Each raft must be equipped with an approved survivor locator light, pyrotechnic signaling device, and a survival kit appropriately equipped for the route to be flown. Rafts are approved per FAA TSO-C70a. Locator lights are approved per TSO-C85 or C85a. Refer to Table 2 to determine which "type" of life raft is required for the category of aircraft operated.

{4} Approved life rafts of a rated capacity to accommodate all the occupants of the aircraft. Each raft must be equipped with an approved survivor locator light, pyrotechnic signaling device, and a survival kit appropriately equipped for the route to be flown. In the event of the loss of the largest life raft, the total overload capacity of all the remaining life rafts must be sufficient to accommodate all the occupants of the aircraft. A minimum of two {2} life rafts are required per aircraft. Rafts are approved per FAA TSO-C70a. Locator lights are approved per TSO-C85 or C85a. Refer to Table 2 to determine which "type" of life raft is required for the category of aircraft operated.

{5} Approved life raft{s} of a rated capacity to accommodate all the occupants of the aircraft. Each raft must be equipped with an approved survivor locator light, pyrotechnic signaling device, and a survival kit appropriately equipped for the route to be flown or contain a canopy, radar reflector, repair kit, bailing bucket, signal mirror, whistle, knife, pump, oars, 75 ft. retaining line, compass dye marker, flashlight, food rations, water rations, fishing kit, and survival manual. Rafts are approved per FAA TSO-C70a. Locator lights are approved per TSO-C85 or C85a. Refer to Table 2 to determine which "type" of life raft is required for the category of aircraft operated.

{6} An approved survival type {"S" Type} ELT attached to one of the life rafts on the aircraft.

Figure 3. FAA Required Emergency Equipment Table (FAA 2012)

Understanding the difference between ditching and inadvertent water landing is important to the study of large life rafts because it determines the probability that the impact will be survivable for both the people and the life rafts. Ditching and inadvertent water landings are classified as two different types of incidences by the FAA. A ditching is defined as controlled flight into water that is planned water contact and meets certain parameters. First, a ditching is an event where the flight crew intentionally lands the aircraft in some body of water (Airsafe, 2009).

Uncontrolled impacts with water are excluded from a ditching definition and apply to inadvertent water landings (Airsafe, 2009). The aircraft should not exceed 300 feet per minute rate upon impact, thus ensuring that the aircrafts' vertical and longitudinal loads is within aircraft design parameters, and the aircrew and passengers have sufficient time in order to prepare for the emergency (McGuire, 1996).

This differs from an inadvertent water landing in that the landing is not planned. In an inadvertent water landing there is not sufficient time to prepare, and the aircraft impacts the water outside of design parameters (McGuire, 1996). The chance of aircraft damage and fatalities among the crew and passengers is much greater in inadvertent water landing giving a lower probability of evacuation and access to survival equipment (McGuire, 1996).

History demonstrates that life rafts are highly valuable to aviation during a water incident. The regulations were created to provide the possibility of survival given a water landing. In the next section, the benefit of large life rafts is explained to illustrate the importance of life rafts and why they are essential to survival to members after a water impact.

Large Life Rafts and Benefits

Life rafts have saved numerous lives over the years by providing protection from the ocean. Large life rafts keep occupants from drowning, becoming hypothermic, and a means to survive for extended periods. The number-one reason for death in water after an incident is drowning (Lounsbury, 2001). Drowning generally occurs because of shock from the incident and the temperature of the water preventing the person from staying afloat (Lounsbury, 2001).

According to a 2002 U.S. Army publication, there are four stages of water immersion: 1) First stage is 0 to 3 minutes; 2) Second stage is from 3-15 minutes; 3) Third stage is greater than

30 minutes; 4) Fourth stage is when the core temperature drops (Lounsbury, 2001). During the immersion phase, the main threat to life is hyperventilation due to panic leading convulsions or heart attack (Lounsbury, 2001). The initial response to cold-water immersion and the stress of the event is the reason why 20% of all those immersed in water will die within the first 2 minutes (Vittone, 2009).

Vittone, an expert on survival in cold water, stated, "it is impossible to die from hypothermia in chilly water unless you are wearing flotation, because without flotation- you won't live long enough to become hypothermic" (Vittone, 2009:8). The thermal comfort zone for a nude human at rest is between 30 to 35 degrees Celsius (Lounsbury, 2002). At temperatures below 23 degrees Celsius, dexterity decreases among your limbs and coordination degenerates rapidly along with the core temperature (Lounsbury, 2002). Continued exposure in cold-water will result in an increased respiration rate leading to raised gas consumption, unconsciousness, and drowning (Lounsbury, 2002).

Immersed in cold water may result in death from drowning, cardiovascular collapse, or both, but *not* from hypothermia (Lounsbury, 2001). Vittone stated that regardless of swimming capability, a person cannot survive for longer than 30 minutes (Vittone, 2009:8). About 23% of the sea, based on temperatures, can be sustained for extended periods (Figure 4) (Science Buddies, 2004).

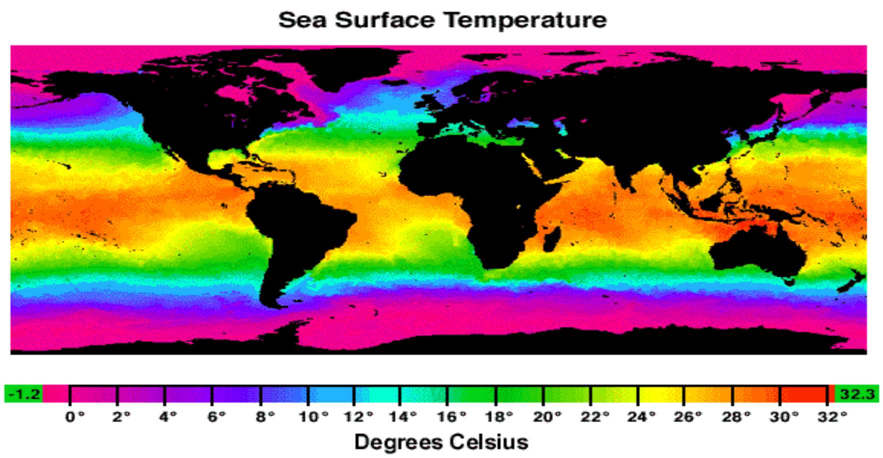


Figure 4. Sea Surface Temperature, (Science Buddies, 2004)

Although many studies show the life rafts protection from the elements through thermal loss, radiation protection, camouflage, etc. the studies do not show the chance that the actual large life raft is used. The survivability rate for an airplane to crash into the open ocean where there are generally swells of more than 3 feet brings one to wonder not if the life raft would be useful but rather it will survive the impact. All too often, crews have found themselves unable to access the life raft or use it because of the flames from the fuel burning on top of the water and on the aircraft; or not being able to inflate the life raft due to the fuselage and wings being torn apart and inflating a life raft would only mean puncturing it. The discussion is not necessarily about whether a large life raft would be helpful but rather the employment method after a crash makes it accessible. The historical foot-print illustrates the importance of large life rafts. However, as technology and the conflicts that the military faces change the analysis on utility of life rafts also needs to be revamped.

To this point, large life rafts have not been used in the C-130, KC-10, C-5, C-17 and KC-135. This means that over the life of these airframes the chance of using a large life raft is 0%.

Due to the lack of information regarding military ditching efforts and use of large life rafts, it is critical to explore civilian aviation water landings and past studies. This research provides a more comprehensive literature review on water landing cases that can be directly compared to aviation in the military.

Main Factors to Ditching

Ditching's occur for a multitude of reasons and this section studies the factors of accidents that occurred in the C-5, C-17, C-130, KC-135, and KC-10 based on geography, conflict, and overall capability of the Air Force crews, maintenance and aircraft reliability.

There are five figures that speak volumes to understanding ditching (Figures 5-9). Analyzing this data is critical to understanding ditching's as they relate to specific conflicts, areas of the world, aircraft reliability combined with better aircrew and maintenance training.

Ditching an aircraft is a rare occurrence (Figure 5). There are 20 total possible ditching events from these U.S. aircraft since their inception and the majority of them occurred during Vietnam (ASN Database, 2013). Fourteen of the 20 ditching events occurred during the Vietnam era, indicating that the Vietnam conflict alone was the main reason for the number of ditching's. However, this information independently does not allude to whether the ditching's occurred because of the geography or the Vietnam conflict.

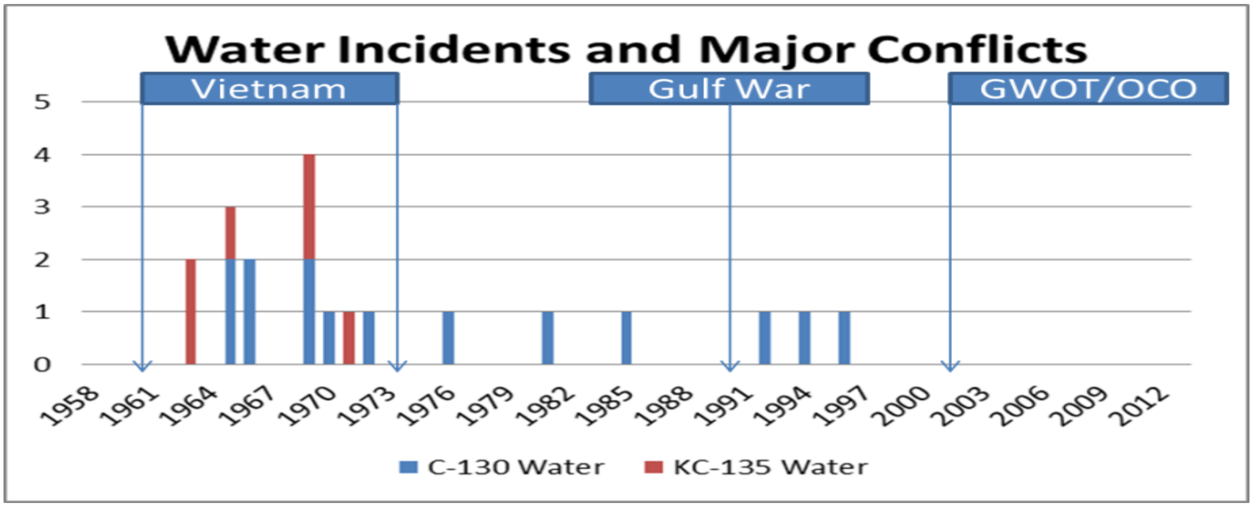


Figure 5. Water Incidents and Major Conflicts. (ASN, 2013)

When this information is combined with the total crashes (Figures 6-7), more of a story is revealed. The total accidents chart by U.S. Military aircraft (Figure 5) is a mirror image of the aircraft losses (Figure 7) except it is amplified indicating that aircraft losses in sea are proportional to the total number of accidents. The total number of incidents also reduced over time revealing that there is a change in aircraft performance and technical abilities of the people handling each flight (Figure 9).

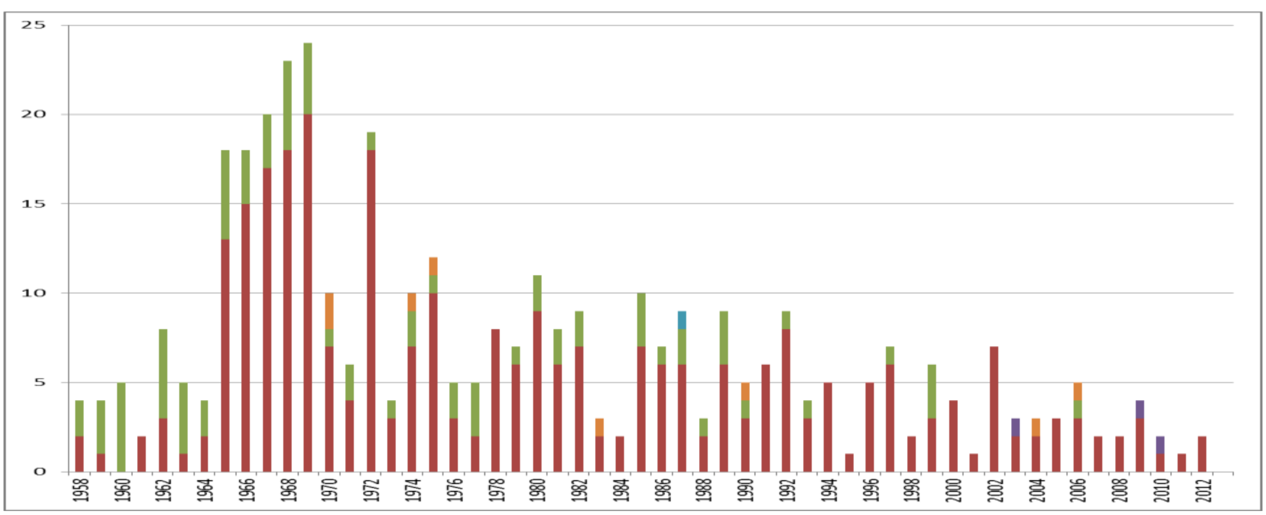


Figure 6. Caption Total Accidents of US Military Aircraft. (ASN, 2013)

Moreover, analysis from the Aviation Network Safety site shows that the rate of aircraft crashes has also reduced by 400% since this period, further indicating that aircraft flight is much more reliable giving credence to aircraft design, aircrew and maintenance capability (ASN, 2013). Second, the war in Vietnam was fought over water more than that of Desert Storm or OCO/GWOT. There was also a higher loss of aircraft during Vietnam and thus more accidents in the water. Crashes in the Pacific Ocean also reveal that flying in this region increases the risk of water landing due to the many areas that are surrounded by water (Figure 8). In summary, the largest factors to an aircraft ditching are: 1) The type of conflict, 2) Aircraft reliability and aircrew and maintenance capability, and 3) Geography.

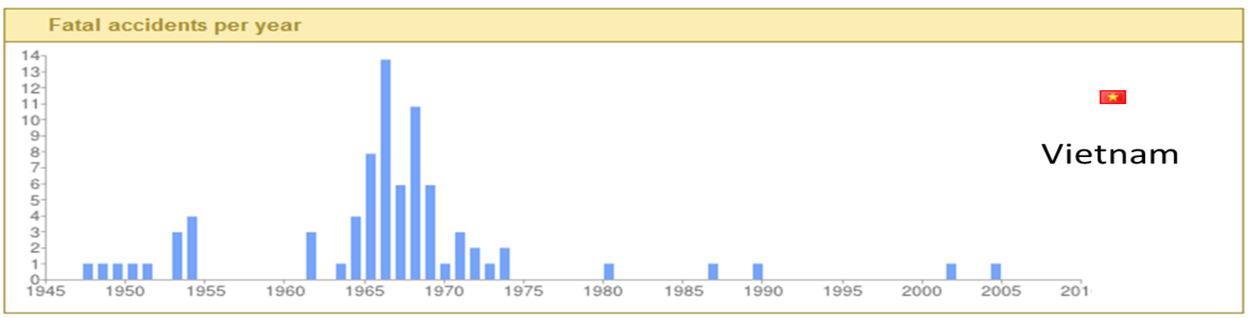


Figure 7. Fatal Accidents in Vietnam. (ASN, 2013)

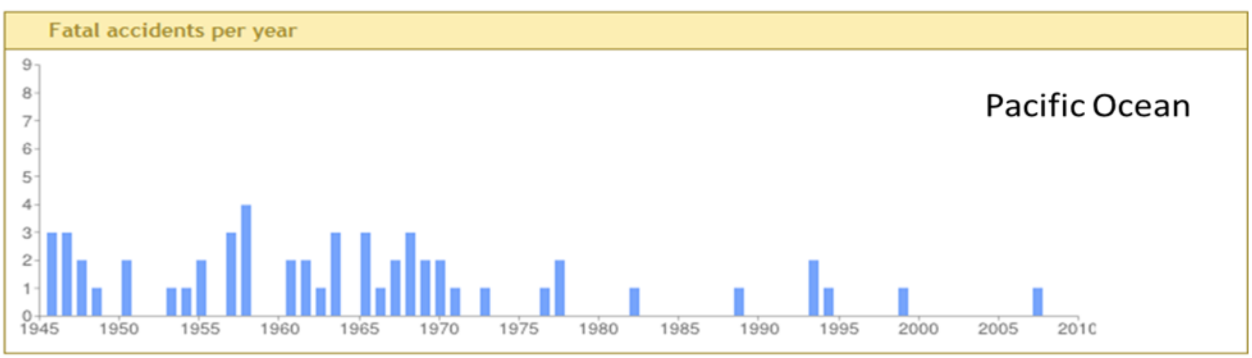


Figure 8. Pacific Ocean Total Crashes. (ASN, 2013)

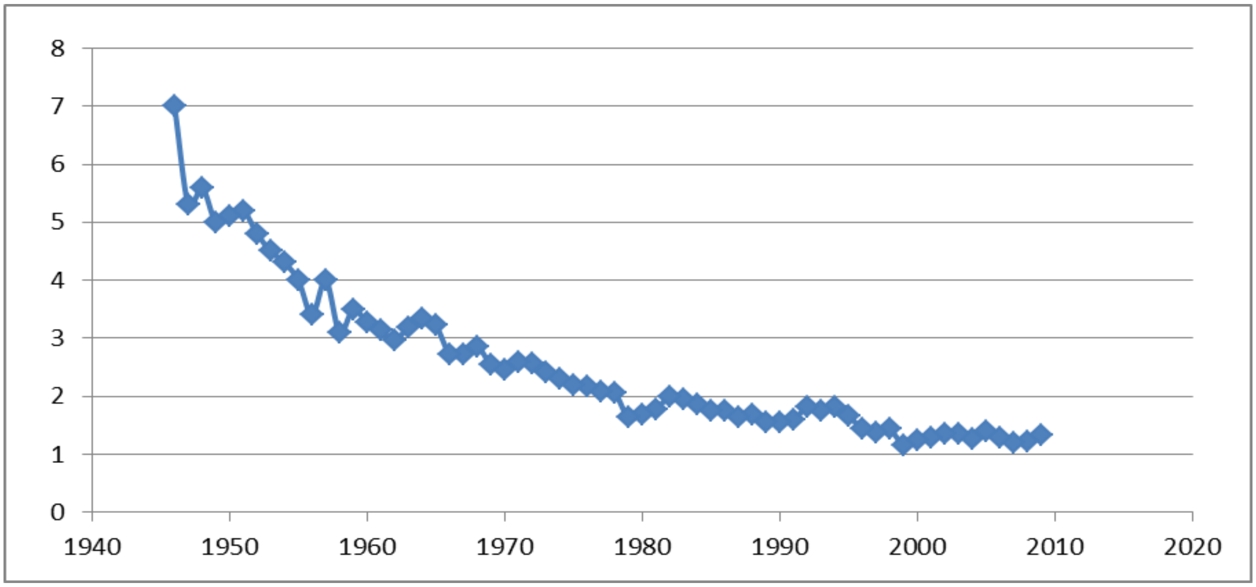


Figure 9. Aviation Fatal Accident Rate Per 100,000 Flight Hours. (AOPA, 2013)

These causes for ditching illustrate incidents primarily for the military aircraft in this study. And since there are few examples, it is critical to incorporate major organizational investigations on ditching and life raft use.

Significant Studies on Ditching

There are a multitude of studies on life rafts in order to improve their effectiveness. Generally, these studies come after a water incident occurred and the safety feature was assessed. This is the case of a thorough study conducted in 1985; the flight that crashed into the Potomac River in 1982 and used life rafts (NTSB 85/02, 1985).

In 1985, the National Transportation Safety Board (NTSB) conducted a safety study on the air carrier overwater emergency equipment and procedures. During this significant study, the NTSB discussed the basic regulatory deficiencies on aircraft, problems with current life preservers, crew training, and airport water rescue planning (NTSB 85/02, 1985). Of importance

to this study, NTSB discussed the need for large life rafts during extended over water flights and need to upgrade aircraft with evacuation slides (NTSB 85/02, 1985).

This study illustrated that most airline water incidents are not planned ditching events. This was an assumption that the FAA had previously made (NTSB 85/02, 1985). This shift in thinking began the discussion at FAA not of the importance of life rafts but rather their employment capability after an inadvertent water landing (NTSB 85/02, 1985). The NTSB stated that none of the accidents were “planned” ditching, except for two from 1959 to 1984 (NTSB 85/02, 1985). Since these water impacts are not planned, there is little or no time for crew and passengers to prepare for the impact (NTSB 85/02, 1985). In addition, the aircraft generally incurs much more damage and is likely to flood and sink quickly (NTSB 85/02, 1985). The fuselage will most likely break apart with wings also becoming dislodged (NTSB 85/02, 1985). Passengers and crew suffer more life-threating injuries if they have survived the impact that makes it even more difficult to escape the aircraft and find a life raft (NTSB 85/02, 1985). Due to the break-up of the aircraft, passengers and crew are quickly immersed in water and chance of hypothermia, and drowning is very probable (NTSB 85/02, 1985).

The NTSB notes that in 1984, the FAA conducted a cost-benefit analysis, in which the FAA concluded that current water survival equipment requirements are adequate and there is no justification for further extensive research, development, engineering or regulatory programs in this area (NTSB 85/02, 1985). The life-rafts, as well as other water survival equipment, are designed for the ditching of an aircraft and not necessarily for an inadvertent water impact (NTSB 85/02, 1985).

Since the introduction of passenger jet airliner services in 1958 there have been 11 survivable air carrier water impact accidents from 1959 to 1979 and 37 total water impact events

(NTSB 85/02, 1985). Most of these incidents occurred during the approach/landing or takeoff/departure phase of flight, thus occurring very close to the airport (NTSB 85/02, 1985). The most distant incident occurred 30 miles from shore (NTSB 85/02, 1985). There have been 13 more survivable air carrier water impacts to the present day (NTSB Database, 2013). Of these accidents five of them have happened on United States carriers with one occurring in the time frame from 1983 to 2013, which was the 2009 crash into the Hudson (NTSB Database, 2013). About 10% of accidents in the water are considered "ditching" while the other 90% are inadvertent water impacts (NTSB 85/02, 1985). Plane crash info cited that of those incidents that were in controlled flight and were considered ditching events only 53% of the passengers survived (PlaneCrashInfo, 2012).

The FAA staff concluded that there are 179 fully certificated airports in the United States located within five miles of a body of water, which is at least a quarter of a square mile in surface area (NTSB 85/02, 1985). There are 256 airports worldwide located near consequential bodies of water (AR-95/54, 1996). Over 75% of all United States approaches are flown over significant bodies of water, which is consistent with foreign airports (AR-95/54, 1996).

This study was a critical shift for aviation because it gave way to the emergence of inadvertent water impacts. This change occurred because of increased capability of flight planning, aircraft reliability, and better trained crews. Nevertheless, it did not change the policy of life rafts.

Five main United States carrier incidents are discussed in the next section because of their importance to FAA regulations and understanding of ditching and inadvertent water landings.

Ditching and Inadvertent Water Landings in the Airline Industry

Although rare, water landings do occur and most often the aircraft does not ditch into the ocean but rather small rivers or bodies of water. This transpires because of the many time-sensitive factors of aviation that occur during the take-off, departure, approach, or landing phase. Water landings in the ocean are rarer because generally, the emergency occurs at a non-critical phase in which the crews have time and altitude to handle the emergency. Furthermore, improved flight and fuel planning, and navigation systems reduces the chance of crew error. This section covers examples from both types of incidents in order to show that the rules provided by the FAA cover aircraft while over large bodies of water but do not regulate areas where an aircraft is not flying under extended over water operations.

Two airline ditching's occurred in 1962 (NTSB, 2013). On September 23, Lockheed 1048H registration number N6923C crashed into the Atlantic Ocean and was destroyed (Figure 10). There were 76 passengers on board the aircraft in which 8 of them were crew members. There were 23 passenger and 5 crew fatalities (ASN, 2013). The aircraft experienced a fire in the number three engine, an over-speed in the number one engine, and the number two engine lost power and failed (ASN, 2013). The aircraft ditched due to insufficient power (ASN, 2013). The winds were reported to be extremely strong creating large swells (Captain Murray, 2011)). Upon impact, the left wing broke off and the aircraft sank in 10 minutes (ASN, 2013). Those who survived the initial impact exited the aircraft within a few minutes and climbed into a large life raft (Captain Murray, 2011). The large life raft was made for 25 passengers but held 51 (Captain Murray, 2011). The life raft was turned upside down and made the survival supplies unreachable (Captain Murray, 2011).

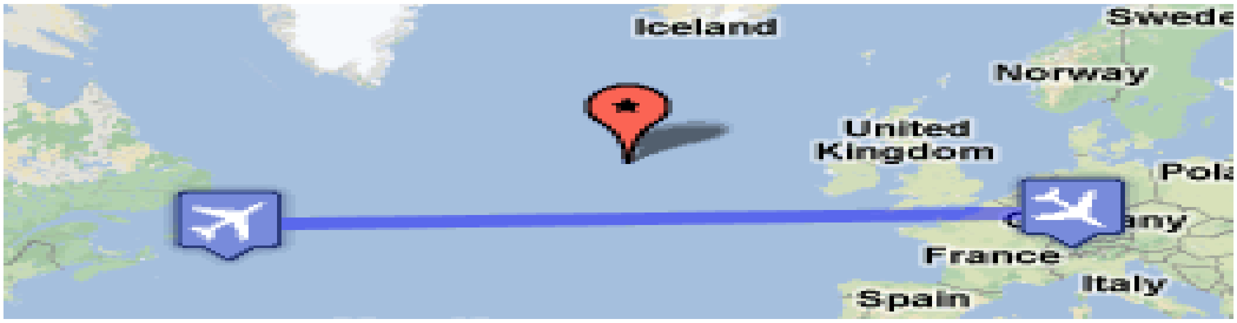


Figure 10. September 23 1962 Lockheed 1049H (ASN, 2013)

After being at sea for 6 hours they were rescued by a Swiss Freighter due to a flash light that was used to signal the freighter (Captain Murray, 2011). The FAA later suggested that life rafts need to be reversible with rim lights visible and emergency kits accessible by both sides (Flying Tiger, 2012). The FAA also suggested that individual life vests must have their own lighting (Flying Tiger, 2012). If the aircraft did not carry the life rafts, more than likely, all passengers would have perished.

During that same year, on the 22nd of October, a DC-7C crashed into the water after 3 hours of flight (Figure 11) (ASN, 2013). This particular flight path is cited as the model for ditching (ASN, 2013). The flight was operating as a military air transport charter flight and had 95 passengers and 7 crew members (NTSB 85/02, 1985). While cruising at 20,000 feet the number-one engine lost power, and the captain elected to ditch (NTSB 85/02, 1985).

The crew and passengers had 45 minutes to prepare for the ditch, and all members could prepare the life-saving equipment, go over procedures, and secure loose-dangerous equipment (NTSB 85/02, 1985). The aircraft ditched in a calm sea, and the contact was smooth (NTSB 85/02, 1985). The aircraft sustained minor damage to the propeller blades, and all passengers

were able to immediately launch life rafts (NTSB 85/02, 1985). The passengers were picked up within 20 minutes by the coastguard and there were no significant injuries (NTSB 85/02, 1985).

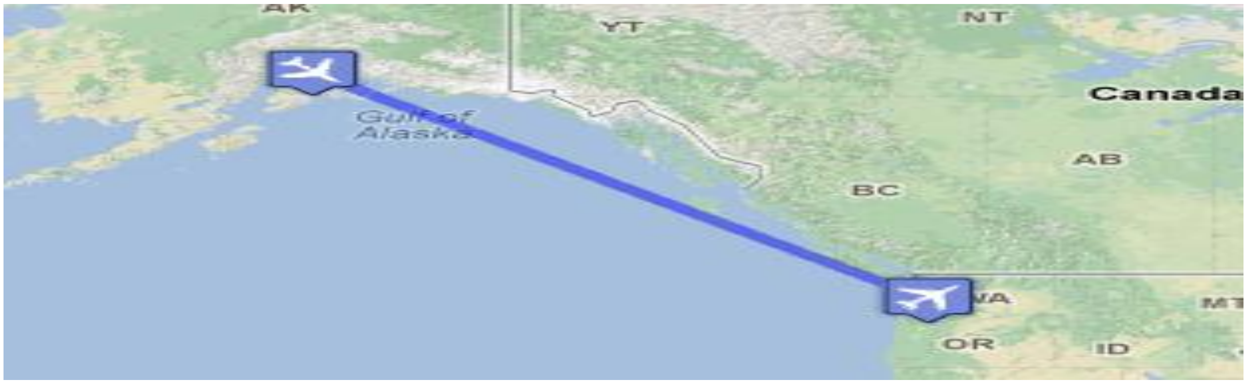


Figure 11. 22 October DC-7C (ASN, 2013)

Another airline ditch occurred on May 2, 1970 in the Caribbean Sea (Figure 12) (AAS-72-2, 1972). There were two missed approaches due to poor alignment with the runway and on the third pass, the aircraft ran out of fuel and ditched into the ocean (AAS-72-2, 1972). There were 63 occupants onboard the aircraft and 23 of them died (AAS-72-2, 1972). The DC-9 aircraft had five life rafts that were stowed near exits in the overhead containers (AAS-72-2, 1972).

After the aircraft ditched, the navigator and two cabin attendants found it impossible to launch the life raft package (AAS-72-2, 1972). The life raft package was heavy and difficult to move outside the aircraft to inflate (AAS-72-2, 1972). The navigator and flight attendants gave up and decided to use the slide as a flotation device (AAS-72-2, 1972). The aircraft sank shortly afterwards leaving the remaining passengers and crew to rally at the slide (AAS-72-2, 1972). The NTSB concluded that slide-raft combination kits should be used (AAS-72-2, 1972). It would ensure that one life raft was always available without the necessity to deal with a cumbersome and time-consuming method of launching the life raft kit (AAS-72-2, 1972). This

crash and report established a precedent for airlines to have the slide-raft combination while flying over-water.

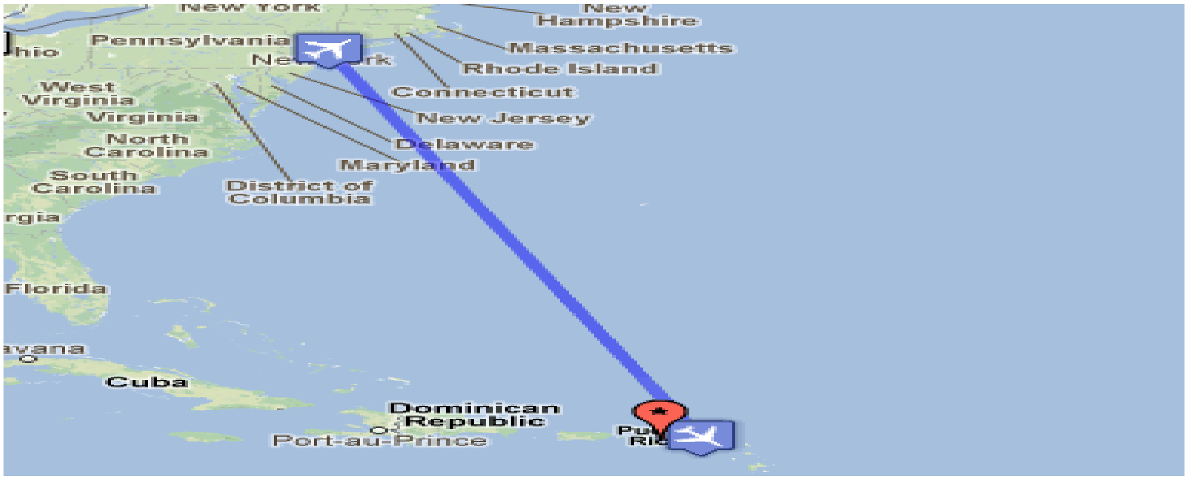


Figure 12. May 2, 1970 DC-9 (ASN, 2013)

These past three examples indicate ditching efforts, instead of inadvertent water landings. These cases illustrate how the amount of time determines the chance of survival and the rational for a different definition of inadvertent water landing. It also illustrates, that in these situations, life rafts were critical to saving lives.

The next cases illustrate how recent water incidents are inadvertent water impacts, in which the crew and passengers had little to no time to prepare or fully control the outcome of the landing.

After attempting to take off with snow and ice on the aircraft, Air Florida Flight 90 crashed onto a bridge and then nosed into the icy Potomac River (Kaye, 2009). Seventy-four of the passengers and crew died and five survived immersed in freezing water (Kaye, 2009). Large life rafts were not deployed but the one airline attendant did gather multiple life vests for the survivors (Kaye, 2009). Some of the onlookers (Figure 13) swam into the water and either

succumbed to hypothermia or rescued the survivors (Kaye, 2009). The remaining survivors were lifted out by a helicopter within 35 minutes of the crash (Kaye, 2009).

Figure 13. Crash into the Potomac. (Kaye, 2009)

Source http://planecrashinfo.com/w19820113.htm

The FAA, policy makers and many leaders in Congress were debating the removal and utility of large life rafts on commercial aircraft. In the Aviation Consumer Action Project, Ralph Nader stated, “a wide-body jet would shatter like a raw egg dropped on pavement, killing most if not all passengers on impact, even in calm seas with well-trained pilots and good landing trajectories” (Slate, 2013). A few years later, the discussion changed based on Captain Sullenbergers heroic act.

On the 15th of January, Flight 1549 crashed in Hudson River (SA-532, 2009). Flight 1549 was an event that greatly influenced the NTSB, FAA, and decision makers on ditching and life rafts, especially since they were not required to have large life rafts on board because the flight path was not over large bodies of water (SA-532, 2009).

There were 150 passengers and 5 crew members on board the aircraft that suffered bird ingestion into both of its engines shortly after takeoff, and lost the thrust needed to maintain flight (SA-532, 2009). Within a short amount of time, approximately 12 seconds, Captain Sullenberger decided to run the Engine Dual Failure checklist in which the first officer spent 30 to 40 seconds trying to restart the engines (Goudou, 2011). Due to the low altitude and loss of power, Captain Sullenberger decided not to land at an airport but rather into the Hudson, (Newman, 2009).

Upon landing, the aircraft had a hard impact but was not violent (SA-532, 2009). The aircraft sustained significant structural damage from the water impact (SA-532, 2009). The right engine was still connected to the wing but the left engine was separated (SA-532, 2009). There was significant structural damage to the airframe due to the high-energy impact at the aft fuselage (SA-532, 2009). It was found that most of the damage was observed on the aft fuselage, from frame (FR) FR49 to FR70, the location (Figure 14) (SA-532, 2009). The NTSB concluded that the damaged increased progressively from little damage at FR47 to more severe damage and loss of the lower portion of the aft pressure bulkhead at FR70 ((SA-532, 2009).

Due to the pitch of the aircraft at impact, the aft section of the aircraft is the first part to hit water. The aft section of the aircraft, therefore, takes the brunt of the impact and receives the most damage. As a result, the life rafts and exits in the rear of the aircraft have a significantly reduced chance of operation.

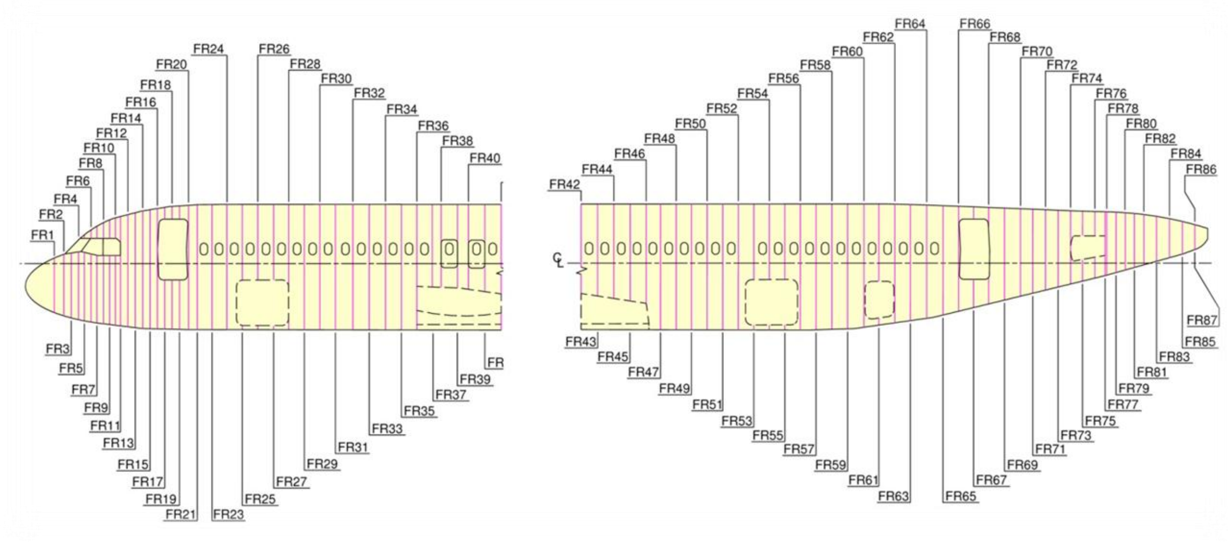


Figure 14. (NTSB/AAR-10/03, 2010)

The aircraft was also not flying over water for extend periods and therefore, did not need to carry the large life rafts, which in many people's minds saved lives. The aircraft was equipped with four slides and four rafts with a capacity of 44 passengers and overcapacity of 55 (SA-532, 2009). There were two rafts in the front of the aircraft and two in the back of the aircraft at stations FR18 and FR68 respectively (SA-532, 2009). These rafts are connected to the slide that is activated at the exit, but the slide does not have a quick release from the A320 (Figure 15) (SA-532, 2009).

Due to the damage of the aft section, the aft exits did not function as desired (SA-532, 2009). After ditching, the two slides and rafts did not function because of the water entry into the aft cabin and structural damage (SA-532, 2009). The slides and rafts were not able to accommodate all the 150 passengers and 64 of the occupants were rescued from the forward slides and rafts, and the other 87 passengers were rescued from the wings (SA-532, 2009). In addition, the slides on the aircraft would have sunk with the aircraft exposing passengers to the cold-water temperatures and increasing the threat to their lives (SA-532, 2009).

Based on this flight, the NTSB concluded that after ditching an airplane the "probable structural damage and leakage will include significant aft fuselage breaching and subsequent water entry…preventing the aft exits and slide/rafts from being available for use during an evacuation" (SA-532, 2009). The NTSB further concluded that in windy conditions or landing in the ocean with swells that the damage would be significantly worse than shown from flight 1549 (SA-532, 2009).

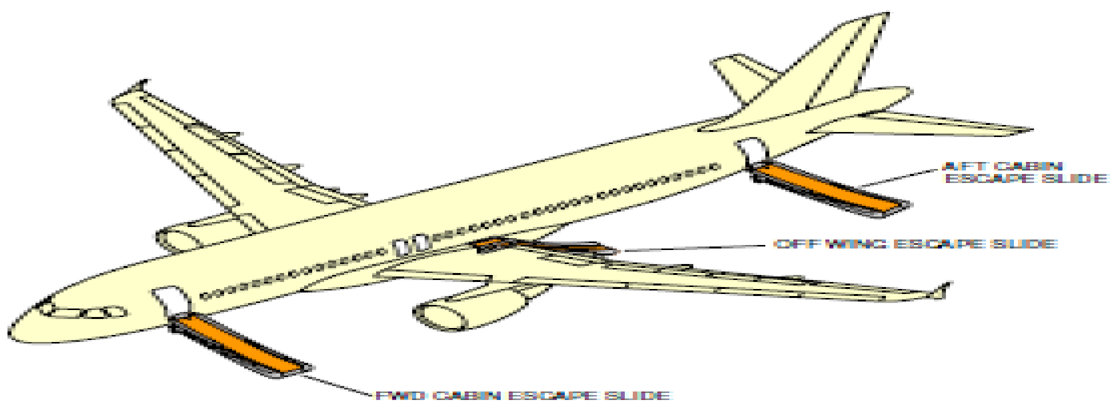


Figure 15 Airbus A320 Slides and Rafts. (NTSB/AAR-10/03, 2010)

These last five cases provide valuable information regarding the most probable scenario, effects, and utility of life rafts while ditching. In four of these incidents, life rafts did either save lives or aid in the rescue of passengers. In addition, the placement and employment of life rafts are important to understand in order to create future policy that provides the best chance of survival. To this point, it is necessary to expand this study and gain similar knowledge on the C-5, C-17, C-130, KC-10, and KC-135.

Life Rafts and Ditching Characteristics on the C-5, C-17, C-130, KC-10, KC-135

The number of large life rafts on board the C-5, C-17, C-130, KC-10, and KC-135 differ as do their sizes, location on the aircraft, and the employment method. It is important to

understand these differences because of the advantages and drawbacks of each major weapon system (MWS) in the event of ditching or water-landing. In total, there have been a total of 20 events in which these aircraft either crashed into the water or exploded before impact (NTSB Database, 2013). Due to the nature of the accidents, it is impossible to tell if all of these aircraft had the opportunity to ditch. Of the six KC-135 accidents over water, three of them were mid-air collisions; one was unknown, and the other two possibly had a chance to ditch (NTSB Database, 2013). The C-130 had 14 incidents over water of which there were only 5 that had enough aircraft control to ditch the aircraft (NTSB Database, 2013). It is difficult to know how each of these aircraft will structurally respond to a water landing because of the limited data especially for the C-5, C-17, and KC-10. However, in the technical manuals of each aircraft, insight is provided on the possible outcome of a ditching effort

C-5 Analysis

The C-5 has a fleet size of 79 of which 29 are C-5As, and 52 are C5B/C/M models (AMC Fact Sheet C-5, 2011). The C-5A fleet is retiring based on Congressional approval and there will be 52 C-5Ms by 2017 (AMC Fact Sheet C-5, 2011). The C-5 has four 25-man life rafts on board that have an overload capacity of 31 that handle a seating capacity of 73 (1C-5M-1, 2011). Three of the life rafts are located in the troop compartment next to the exits, and the fourth one is located in the aft section of the flight deck (Figure 16, 17) (1C-5M-1, 2011). The life rafts are automatically inflated once they are activated, and they will eject out of the aircraft (1C-5M-1, 2011). The C-5 also has five slides that are located at the exits (1C-5M-1, 2011).

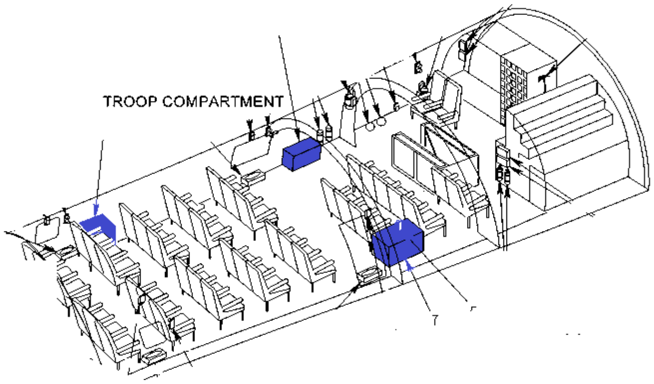


Figure 16. C-5 Troop Compartment Raft Location

(1C-5M-1, 2011)

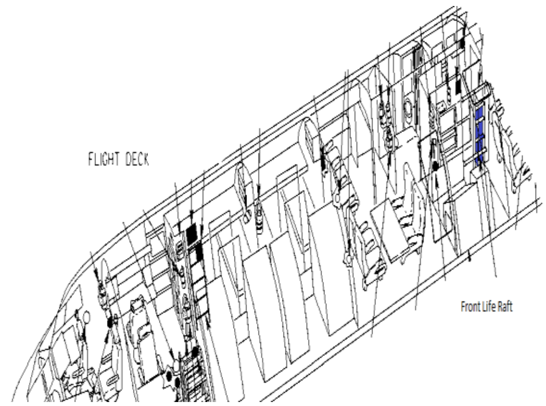


Figure 17. C-5 Flight Deck Raft Location

(1C-5M-1, 2011)

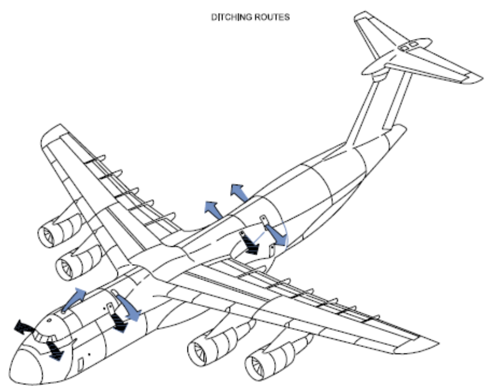


Figure 18. C-5 Emergency Exit Locations

(1C-5M-1, 2011)

The C-5 ditching characteristics, based on the flight manual, state that it is expected to "exhibit smooth motions during the ditching maneuver and the basic fuselage shell, ramps, crew entrance and troop doors will sustain ditching pressures" (1C-5M-1, 2011). The flight manual instructs crews to ditch parallel to the swells unless the wind is greater than 30 knots in which it is best to land into the wind (1C-5M-1, 2011). The aircraft should be depressurized, loose

equipment stowed, flaps down, main landing gear down and the nose gear up (1C-5M-1, 2011). This is the first manual that recommends leaving the main gear down during a ditching event.

As the aircraft approaches the water, the pilot should have a normal landing attitude and ensure the aircraft does not stall (1C-5M-1, 2011). The flight manual estimates that the personnel in the flight deck and in the troop deck will have plenty of time to evacuate the aircraft due to the flotation capabilities of the aircraft and high location of the seats (1C-5M-1, 2011).

The C-5 has had eight crashes since 1970, in which four of them occurred from 1970-1975 (ASN Database, 2013). The C-5 has not been involved in a ditching incident or had to utilize any of the large life rafts due to a water impact (ASN Database, 2013).

C-17 Analysis

The United States Air Force has purchased 223 C-17s (Air Force Fact Sheet C-17, 2011). The C-17 has three 46-man life rafts (1C-17A-1, 2012). The overload capacity of each life raft is 69, and located in the front of the wing root and in the aft section of the aircraft (Figure 19) (1C-17A-1, 2012). There are five locations that can eject the life rafts and upon activation, a semi-rigid ladder will fall at four locations (1C-17A-1, 2012). The life rafts are ejected and tethered by a string (1C-17A-1, 2012). There are 16 possible exits from the aircraft in which, 6 exits are on top of the aircraft (1C-17A-1, 2012). Eight of the 16 exits are located in the front of the wing root, and the other half is in the back section of the aircraft (1C-17A-1, 2012).

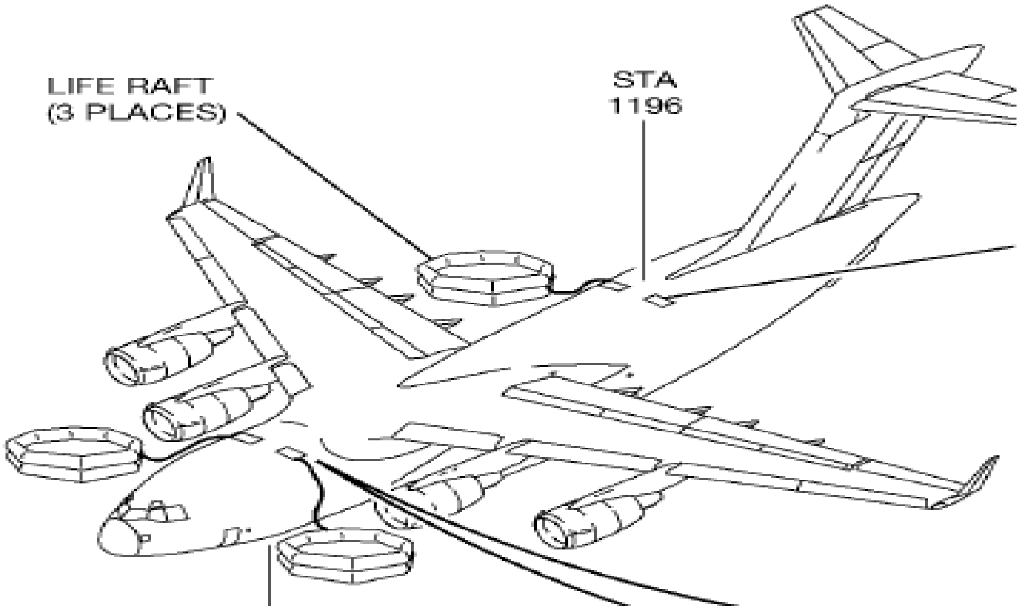


Figure 19. C-17 Life Raft Location and Emergency Exits (1C-17A-1, 2012)

The flight manual does state that ditching may or may not be favorable to bailing out of the aircraft due to the sea conditions and aircraft controllability (1C-17A-1, 2012). The technical order does state that as long as the ditching occurs with the main body contacting the water first, the aircraft should be in a condition in which some or all the exits are usable (1C-17A-1, 2012). The aircraft will also float long enough for passengers to climb the ladders and evacuate the aircraft (1C-17A-1, 2012). The flight manual does not provide an attitude to attain at impact but does state that the aircraft should reduce gross weight by jettisoning any remaining fuel, stow and secure loose equipment, set flaps in the ¾ detent position and land at normal approach speeds (1C-17A-1, 2012).

A C-17 has never ditched or used the large life raft in a water incident, but there have been three major incidents that occurred in 2003, 2009, and 2010 (ASN Database, 2013). In 2003, a C-17 was hit by a surface-to-air missile and returned safely back to base (ASN Database, 2013). In 2009, the crew landed the C-17 on the runway without lowering the gear (ASN

Database, 2013). There was significant damage to the belly of the aircraft and a fire, but the aircraft remained intact (ASN Database, 2013). The accident in 2010 occurred while the crew was practicing maneuvers for an upcoming Air Show and the aircraft stalled and crashed (ASN Database, 2013).

C-130 Analysis

There are three main models, E/H/J, of the C-130 that are a part of this analysis. There have been 993 C-130's built for the United States Air Force since 1958 (Air Force Fact Sheet, 2011). Each C-130 model has four 20-man life rafts, except for some C-130Js that have two 46-man life rafts (C-130E (H)-1, 2009). Two life rafts are stored on each wing root of the C-130 (Figure 20) (C-130E (H)-1, 2009).

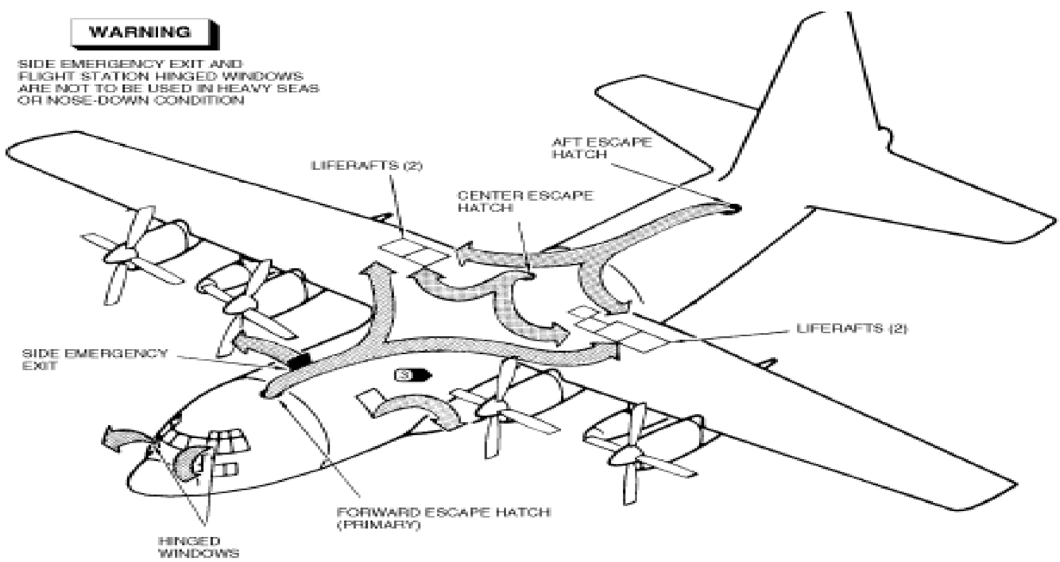


Figure 20. C-130 Emergency Exits (C-130E (H)-1, 2009)

The life rafts are actuated by pulling of the life raft release handle, which is in five locations with one additional handle on the actual wing (Figure 21) (C-130E (H)-1, 2009). These handles are located close to the aft, center, and forward escape hatch (C-130E (H)-1, 2009). After pulling these handles the life rafts should inflate and are tethered to the aircraft after they eject from the wing (C-130E (H)-1, 2009). In order to evacuate the center hatch a ladder must be installed (C-130E (H)-1, 2009). The manual does not provide any information on how far the life raft is ejected from the wing. This is obviously important in most situations due to the possibility of a fire, and exposed sharp edges from the damaged aircraft.

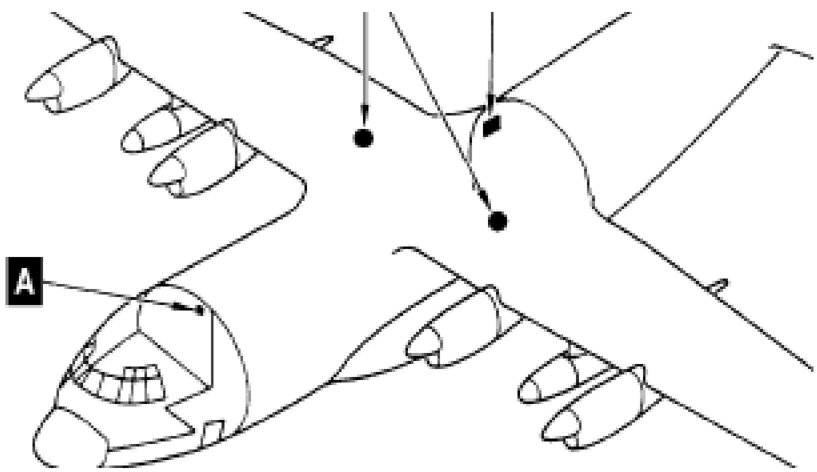


Figure 21. Life Raft Emergency Pull Locations (C-130E (H)-1, 2009).

The C-130 flight manual states that "actual experience in ditching the C-130 has determined there is a reasonably high probability the airplane structure will collapse followed by a sudden rush of water into occupied compartments…severe bottom damage will occur" (C-130E(H)-1, 2009: 3A-89). There is a warning in the flight manual that also states, "Flooding of the ruptured fuselage compartment may occur within seconds, severely hampering egress from

the airplane" (C-130E (H)-1, 2009: 3A-89). The West Newspaper published an article on the crash of King 56 and stated that "even in the best-executed ditching, the C-130's fuselage has ripped and flooded, turning the 40-foot cargo bay into a death chamber" (The West, 1997: 3A-4A). These warnings are based on the assumption that the aircraft has partial power and will land with a 7 degree nose high pitch attitude, full flaps, landing gear retracted, and ten knots above power off speed (C-130E (H)-1, 2009). Any deviation from these parameters will increase the likelihood of damage to the aircraft (C-130E (H)-1, 2009: 3A:89). This is important to note because the crash of a C-130 will change the exit options available to the crew as well as the passengers on board the aircraft. There are assumptions about the exits and about the employment and location of the large life rafts that may make them usable only under certain conditions.

In the flight manual, the ditching procedures are to bring the aircraft on to water in the safest possible configuration. There are multiple scenarios in the flight manual. These scenarios are: 1) Normal Power-On Ditching, 2) Partial Power Ditching, 3) Crosswind Ditching, 4) Upwind Ditching, 5) Night Ditching (C-130E (H)-1, 2009: 3A-90). Each one of these scenarios recommends different procedures and special precautions that should improve the chances of a successful ditching effort.

C-130 Crash Data and Location

Of the aircraft in this study, C-5, C-17, C-130, KC-10, and KC-135 the C-130 has had the most crashes and water incidents (NTSB Database, 2013). There have been a total of 165 crashes that resulted in the hull- loss of the aircraft (NTSB Database, 2013). The reason for the

large number of incidents is due to the number of C-130s that exist. In this analysis, the C-130A, B, E, H, J models as well as any other variant owned by the United States is included.

There were 79 hull-losses from 1958-1969 with a total of six crashes that involved the aircraft departing or impacting the water (Figure 22) (NTSB Database, 2013). From 1970-1979, there were 41 incidents with 4 water incidents (NTSB Database, 2013). From the period of 1980-1989, there were 22 incidents and 2 water incidents (NTSB Database, 2013). In the 1990s there were a total of 12 incidents and 3 of those were involved with bodies of water (NTSB Database, 2013). From 2000 to present there have been 11 crashes in which none of them involved large bodies of water (NTSB Database, 2013). Of these incidents, about 62% of them occurred near or at the airport where 38% occurred while en route (NTSB, 2013).

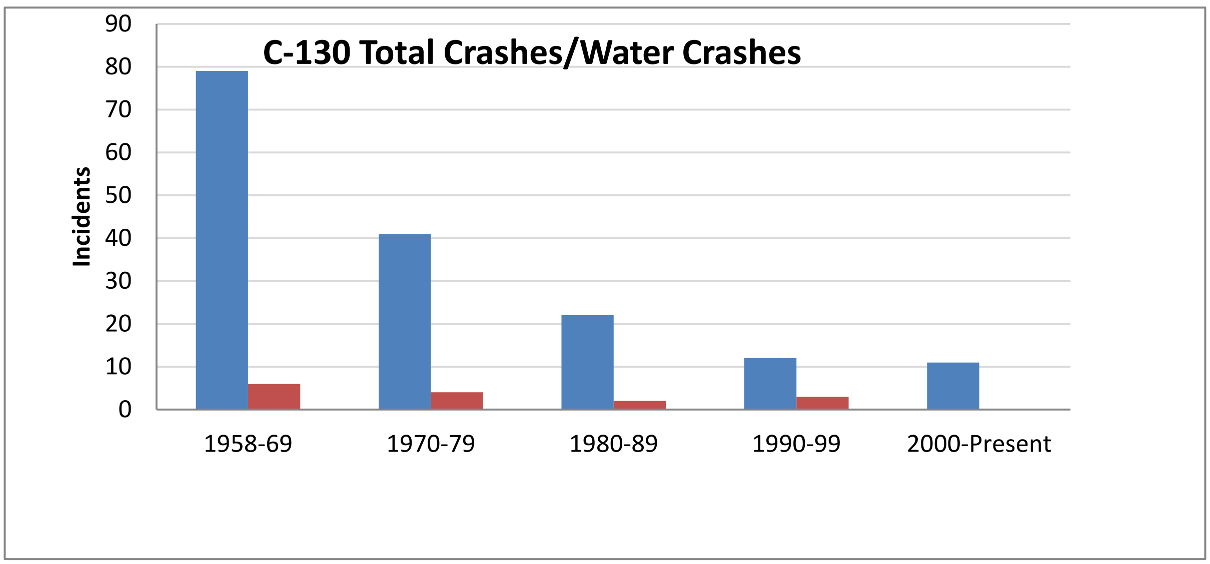


Figure 22. C-130 Total Crashes versus Water Crashes (ASN, 2013)

Figure 23. C-130 Map of Crashes (ASN, 2013)

Out of the 14 C-130 crashes into water, 9 of them occurred while en route and 5 occurred close to its departing or arriving airport (NTSB Database, 2013). Of those incidents, at least three of them were classified as ditching incidents and the other incidents were either unknown or uncontrolled crashes into the large bodies of water in which one landed into a lake (NTSB Database, 2013).

Of the total C-130 hull losses that occurred in water, there have been 112 crew members killed, 13 crew survivors, 90 passengers killed, and 10 passengers survivors (NTSB Database, 2013). The surviving passengers were not in the hull at the time of the water impact (NTSB Database, 2013). Only two members have ever survived while in the hull of the aircraft during a water impact of a C-130 (NTSB, 2013).

C-130 Water Incidents

There are two C-130 accidents that are analyzed in this section. HC-130P aircraft with tail number 65-14856 ditched in the Pacific Ocean off of the California coast on 22 November,

1996 with call sign King 56 (NTSB Database, 2013). The second crash was an AC-130 that ditched off of the coast in Kenya after catastrophic failure from a 105mm cannon (Spectre, 2008). Both examples demonstrate that the C-130 aircraft does not fare well in a ditching attempt. The hull of the aircraft is extremely dangerous because of the initial impact and subsequent forces that destroy the hull; either killing the people in the hull on impact or making it a trap filled with water.

King 56

After 1 hour and 22 minutes, King 56 began to have engine problems and about three minutes later all engines flamed out (Floyd, 1998). King 56 was at 22,000 feet and began descending at a speed of 200 miles per hour (Floyd, 1998).

While descending the crew tried to troubleshoot the problem but was unable to resolve the emergency (Floyd, 1998). The crew did consider jumping out of the aircraft, but decided that it would be safer to ditch. They were not far from the coast and began preparing the aircraft at approximately 7,000 feet by opening the aircraft hatches (Young, 1997). Of the 11 crew-members, all died from the impact except for the radio operator who was TSgt Vogel (Young, 1997).

The radio operator stated that there was a large crash and was thrown out of the aircraft (Young, 1997). He thought that he heard a voice but he never saw anyone in the eight foot swells (Young, 1997). The radio operator did see one of the 20-man life rafts but it was shredded so he used a seat cushion from the cockpit instead as the aircraft quickly sank (Figure 24) (Young, 1997). He was picked up about 3 hours later by a coast guard helicopter and survived by holding his seat cushion (Young, 1997). There were two other crew members that were found

as they found parts of the aircraft and it was determined that they died from the water impact (Young, 1997).

At the time, the crew was trained that ditching a C-130 was safer than jumping from the aircraft (The West, 1997). In the C-130 Broad Area Review, it states that ditching is favored over bailout, and the review recommended that the priority should "be reviewed and revalidated in light of available ditching information" (Floyd, 1998). The priority did subsequently change, and the flight manual states "statistical survival rates for over water bailout exceed ditching survival rates" (C-130E (H)-1, 2009: 3A:81).

Engineers stated that there were no tests on the C-130 in ditching scenarios and found that similar cargo planes, with wings set high on the fuselage, ditched poorly (The West, 1997). They further stated that the cargo portion of the aircraft would sink quickly because the surface area of the wings is on top of the fuselage (The West, 1997). If the fuselage was broken, the entire aircraft would rapidly sink (The West, 1997). Two of the engineers of the C-130 concluded that "fliers seated on the flight deck of a C-130 stood a fair chance of surviving," but did not like the chances of the passengers in the cargo hold (The West, 1997). In fact, they stated that the hull of the aircraft was a death-trap for anyone (The West, 1997). The hull breaking is very likely, and the rush of water into the hull due to the high swept wings provides little opportunity for one to escape (The West, 1997).

Since 1996, there were 16 C-130s world-wide that had a water incident in which only 6 of them were survivable and only 20 of 236 people survived (The West, 1997). The cargo compartment has a very low rate of people surviving, and only 2 of 22 aircrew members have ever survived in the cargo bay (The West, 1997). This analysis is similar to the accident of

Jockey 14 except the fact that Jockey 14 was able to better control the aircraft into the water and had more time to prepare for the ditching effort.

Figure 24. King 56 Salvage. (NTSB 2013)

Jockey 14

During Operation CONTINUE HOPE an AC-130 crashed off of the coast of Kenya (Spectre, 2008). The aircraft experienced catastrophic failure while firing a 105mm cannon and the aircraft soon lost the ability to maintain altitude and ditched (Spectre, 2008). Three of the four members bailed out of the aircraft and survived. The remaining 10 perished from the ditching event (Spectre, 2008). Jockey 14 provides critical information to the survivability of a C-130 ditching and the utility of large life rafts after an accident.

On this fateful day, Jockey 14 was unable to maintain altitude due to multiple engine loss (Jockey_14, Safety). After attempting to fight the fire, the crew was ordered to abandon the aircraft at which time the crew in the back of the aircraft began to bail out (Jockey_14, Safety).

Four of the 11 members in the hull were able to exit the aircraft before impact (Jockey_14, Safety).

As the aircraft continued to descend, the crew realized that the aircraft was going to ditch and prepared for a crash landing (Jockey_14, Safety). The crew removed the emergency exits prior to touchdown, which was in accordance with ditching procedures (Jockey_14, Safety). The aircraft was still powered by the two engines, but did not have enough to make it to land, and impacted the water at a normal speed and attitude (Jockey_14, Safety). The aircraft bounced several times before coming to a rest (Jockey_14, Safety). The front crew tried to egress the aircraft at multiple locations but are forced to abandon those efforts because of the water rushing in (Jockey_14, Safety). However, two of the four front crew members were able to exit the copilots swing window while the third exited out escape hatch almost drowning (Jockey_14, Safety). Once the crew was out of the aircraft, they began to scope the area to see if there were any other survivors while standing on the wing (Jockey_14, Safety).

The aircraft was touching the bottom, and so it did not sink: providing a platform to stand on. A voice was heard and they immediately swam over with a small life raft (Jockey_14, Safety). While swimming, the crew member was pushed into the aircraft and the single-man raft punctured (Jockey_14, Safety). Upon reaching the drowning member, a weak pulse was noted, and the member died from the injuries (Jockey_14, Safety).

Six of the seven crew members in the hull sustained fatal injuries from the impact while one drowned after a nonfatal head injury (Jockey_14, Safety). It is important to understand the impact forces to the C-130 because if the aircraft can't survive a ditching effort than the life rafts are useless. Additionally, if the large life rafts are not functional after a water impact, then again, there is no utility.

It is important to analyze the reason why life rafts have not been utilized on past incidents so they can be removed or altered. In the next section, the report of Jockey 14 will reveal much of this information.

One of the main findings dealing with the integrity of the aircraft was that the flight deck was the only survivable area on the aircraft upon impact (Jockey_14, Safety). Although none of the crew members in the cargo compartment were restrained at the time of the impact, it was found that the entire cargo compartment was non-survivable due to the tear up and disintegration of the floor, seat areas, and shifting of heavy cargo contents (Jockey_14, Safety). The seat location and type (Figure 25) are different than that of a C-130 model. The AC-130H has a total of 21 seat positions, 9 of them are forward facing, track-mounted, four-point restraining harness that are located on the flight deck and in the front section of the aft compartment (Jockey_14, Safety). The other seats are floor-mounted, rear-facing, fold up crash seats with lap-belts only (Jockey_14, Safety).

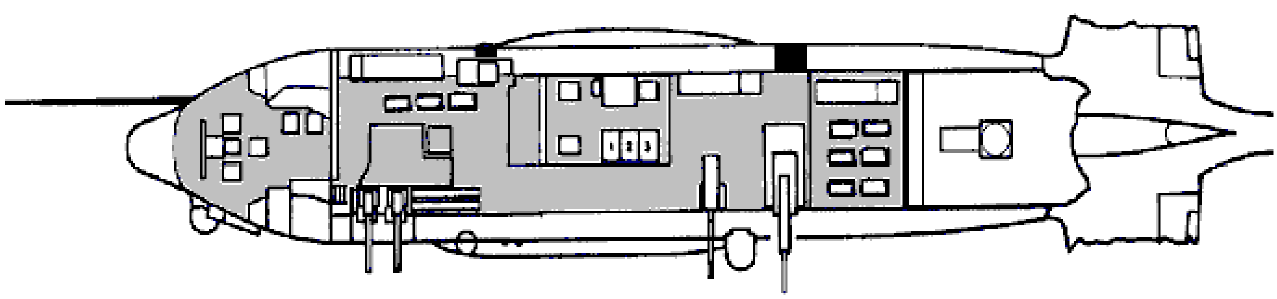


Figure 25. AC-130 Seats Flight Deck and Hull (Jockey_14, Safety)

Source: http://www.leiden3e.com/ward20m/obs-AC130USpooky.htm

The aircraft struck the water in a slightly nose-high position at speed and descent profile commensurate with the technical orders (Jockey_14, Safety). The fuselage was torn into two at

the leading edge of the wing and the wing sheared off (Jockey_14, Safety). The flight deck area was left virtually intact with little damage but the floor of the cargo area was torn apart (Jockey_14, Safety).

The crash occurred in very shallow water allowing the aircraft to still stay somewhat surfaced (Jockey_14, Safety). If this event occurred in deeper water or at night the ability to exit would have proved to be much more difficult (Jockey_14, Safety).

In conclusion, the cargo compartment was found to be un-survivable due to the impact, but the flight deck was survivable if properly restrained in the seats (Jockey_14, Safety). This shows that the possibility of surviving the impact of the ditch is only likely if the individual is in the flight deck and strapped in. However, if passengers or other crew members are in the hull of the aircraft during the impact, the chance of survival is near zero. Surviving the impact is slim, but what about employing and using a life raft?

The post-crash scenario of Jockey 14 illustrates that the life-support equipment on the aircraft is likely not to work after a crash into the water. Fortunately, for the crew of Jockey 14, they were near a coast and in shallow water expediting the rescue and allowing them to remain on the aircraft (Jockey_14, Safety). This next section will analyze the use of life rafts, their utility, and survivability post-crash.

The crash of Jockey 14 illustrates that the equipment the crew had access to, after the water impact, would not have sustained life for a significant period of time (Jockey_14, Safety). The first major concern is the ability for passengers and crew to survive post-ditch. There were two 20-man life rafts and none of the members actuated the life rafts (Jockey_14, Safety). This illustrates that the locations of the raft actuation handles were problematic to this situation. This incident, even though the aircraft flew into the Ocean based on the ditching parameters, they did

not have time to actuate the life rafts. This signals that the aircraft, if landed on water, will most likely not provide the time for the crew to employ the life rafts. However, the life rafts could be employed on the wing once out of the aircraft so long as the aircraft is still floating. Unfortunately, the crew did not use the life rafts even though they were on the wing because they were damaged.

The large life rafts were destroyed and inaccessible after the crash (Jockey_14, Safety). The life rafts were believed to have been separated from the aircraft and were destroyed after water impact (Jockey_14, Safety). One 20-man life raft, located in the wing root, was destroyed and had multiple tears along the raft (Jockey_14, Safety). The actuation bottle was torn from the raft as well as the manifold valve (Jockey_14, Safety). The additional 20-man life raft also had multiple tears along the raft (Jockey_14, Safety). Besides, the second raft was burned making it unusable (Jockey_14, Safety).

This incident reveals information about the ditching of a C-130. This incident serves as an example where the ditching parameters were met, but the hull of the aircraft was destroyed along with the large life rafts. In the event that a C-130 was carrying passengers, and ditched, the result would likely be an awful tragedy. The passengers would most likely not survive the impact and immediate rush of water. If the passengers in the hull did survive the impact, the likelihood of exiting the aircraft has shown to be just as difficult. As this situation is bleak, passengers still need to survive the open ocean with a very high probability of no useful life rafts. Alternatively, the crew on the flight deck would most likely survive the impact to only find that the large life rafts were destroyed.

KC-10

There are 59 KC-10s in the Air Force and has a basic crew of four (Air Force Fact Sheet KC-10, 2011). There has only been one loss of a KC-10 which occurred on the ground due to an explosion while refueling (ASN Database, 2013).

The KC-10 has a different set of life rafts than the other aircraft and is equipped similarly to a typical airline aircraft. The KC-10 can change out the doors on the aircraft that can hold slides or slides and rafts (1C-10KA-1, 2012). The aircraft has the slide and life raft combo on doors 2L and 2R, when the aircraft is configured for 75 personnel (Figure 26) (1C-10KA-1, 2012). Doors 2L and 2R are at the front section of the aircraft.

The aircraft can be configured to have four slide and life raft combos that are stationed at 1L, 1R, 2L, and 2R with a normal handing capacity or 25 per raft or overload capacity of 31 (1C-10KA-1, 2012). The forward galley also houses a seven-man life raft for the crew (1C-10KA-1, 2012). The slide and life raft combo can be released from the aircraft and used during a ditching event (1C-10KA-1, 2012). If the doors that house the slide land raft cannot be opened, then the slide and life raft combo can be moved to a different exit (1C-10KA-1, 2012).

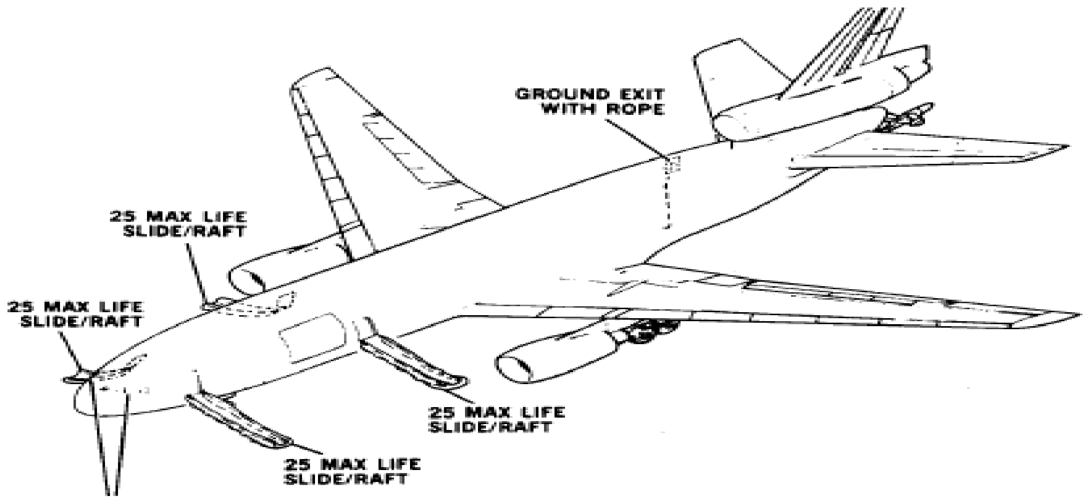


Figure 26. KC-10 Slides and Rafts, (1C-10KA-1, 2012)

The ditching procedures of the KC-10 state that the aircraft should empty fuel tanks, configure with full flaps and gear up, and depressurize the aircraft (1C-10KA-1, 2012). In addition, it is important to reduce forward speed and descent rate (1C-10KA-1, 2012). The aircraft should contact the water with a ten degree nose up attitude, and it is best to touchdown parallel to the waves (1C-10KA-1, 2012). After contact with the water, the aircraft is designed to float for a long amount of time, which depends on the structural damage (1C-10KA-1, 2012). However, the manual states that it is imperative to evacuate immediately even if the aircraft is structurally sound (1C-10KA-1, 2012).

The DC-10, which is the civilian equivalent to the KC-10, has 52 accidents world-wide, but none of them have been involved in any type of water incident (ASN Database, 2013). The only KC-10 incident occurred in 1987 when it exploded on the ground during refueling (ASN Database, 2013). There is not a documented case of a KC-10 ditching or ever using the large life raft on water (ASN Database, 2013).

KC-135

There are currently 414 KC-135s in the Air Force in which 167 are in the active duty, and 247 are in the Guard and Reserve (Air Force Fact Sheet KC-135, 2011). The life raft on the KC-135 is different than the other platforms because it is not integrated in the wing root or the exit doors (1C-135(K) R (II), 2012). Up to three 20-man life rafts may be carried on flights dependent on the mission and passenger load (AFII-2KC-135V3_ADDENDA-A, 2012). Since life rafts can be removed easily, the community of the KC-135 has removed the life rafts when the mission does not require them.

For example, on a programmed depot maintenance flight (PDM), the aircraft can fly without 20-man life rafts unless they fall under the FAA extended over water flight rules in which they would then carry one 20-man life raft (AFII-2KC-135V3_ADDENDA-A, 2012).

The capability to remove life rafts provides a capability of using them during over-water bail out by releasing them while flying and next jumping out of the aircraft (1C-135(K) R (II), 2012). Additionally, the life rafts can be moved to different exits easily, after ditching, that may allow for a safer exit and viable raft (1C-135(K) R (II), 2012).

The preference of evacuation, based on the flight manual, is to egress on the wings and inflate the life rafts once you are clear from any airplane debris (1C-135(K) R (II), 2012). The life rafts are located on station 720 which is next to the over-wing exit (Figure 27) (AFII-2KC-135V3_ADDENDA-A, 2012). On the other hand, ditching or using them before bailing out over water takes special precautions to ensure that they are not inflated inside the aircraft because they will not fit through the exits and could cause difficulty in departing the aircraft (1C-135(K) R (II), 2012).

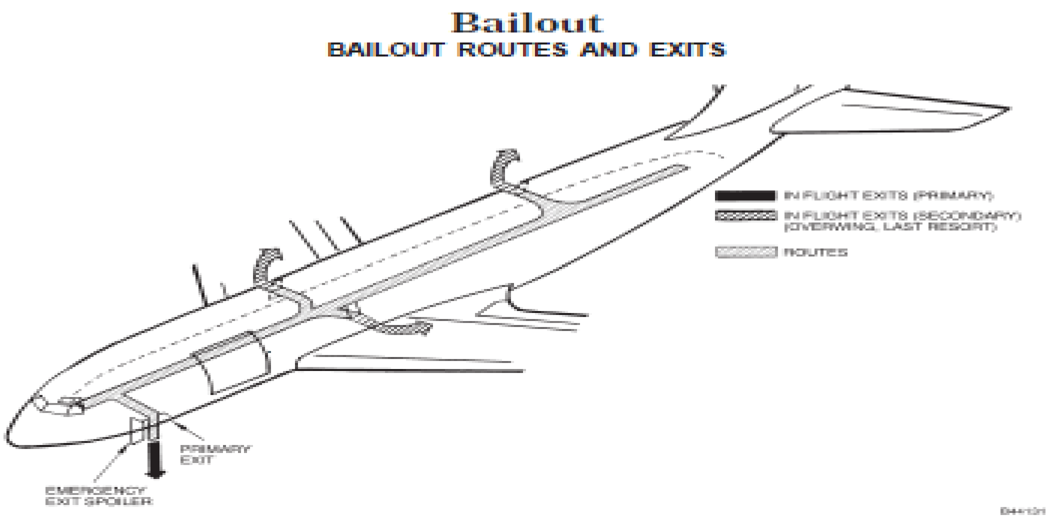


Figure 27. KC-135 Emergency Exit Locations (1C-135(K) R (II), 2012)

The ditching procedures in the KC-135 flight manual are similar to those in the other platforms. The directives state that the aircraft should land parallel to the swells unless the wind is greater than 30 knots (1C-135(K) R (II), 2012). The KC-135 should ditch with use of flaps, and the landing gear up (1C-135(K) R (II), 2012). Flying at the slowest possible forward speed and have a low descent rate upon contacting the water is important (1C-135(K) R (II), 2012). Normal nose up attitude should be used, and the aircraft should never be come close to stall speed because of the large structural damage to the underside or cart wheeling due to one wing dipping (1C-135(K) R (II), 2012).

The KC-135 has experienced six accidents over large bodies of water in which none of them were survivable (ASN Database, 2013). Six aircraft were lost; 59 crew members and 3 passengers lost their lives (ASN Database, 2013). Of the six accidents three of the accidents were mid-air collisions that occurred while performing air refueling, and it is unknown if the crew had any capability to control the aircraft (ASN Database, 2013).

A different crash occurred on the 5th of June 1969 in which the details about the crash are unknown other than it went into the sea after having mechanical problems (ASN Database, 2013). No wreckage was found (ASN Database, 2013). That same year on the 19th of December, a KC-135 crashed into the sea shortly after takeoff due to wind-shear (ASN Database, 2013).

On the 24th of September in 1968, a KC-135 was flying to Honolulu Airport in Hawaii from Anderson Air Force base in Guam (Figure 28) (ASN Database, 2013). The aircraft had engine problems, and the crew decided to divert to Wake Island Airport, and on approach, the aircraft contacted the water short of the runway and skipped onto the east side of the runway (ASN Database, 2013). The rear of the aircraft did separate from the aircraft (Figure 29) (ASN Database, 2013).

Figure 28. Wake Island Visual Approach. (ASN, 2013)

Figure 29. KC-135 Aircraft After Ditch and Crash on Land (ASN, 2013)

The KC-135 has had 79 incidents where the aircraft was lost (ASN Database, 2013). Of these incidents 42 of them occurred during takeoff, approach or departure (ASN Database, 2013). Fifty-six of the incidents occurred in the KC-135A model, three occurred in the B and E Model,

and one accident occurred in the R model. There has been a steady decline of accidents. The periods from 1958-1969, 1970-1979, 1980-1989, 1990-1999, and 2000-present has 40, 13, 16, 4, and 0 accidents respectively (ASN Database, 2013). There has not been a documented case that the KC-135 has used a large life raft or had a successful ditching (ASN Database, 2013). The KC-135 models have continued to achieve better reliability over the years leading to fewer accidents per million flight hours. Unfortunately, there have been no survivors from past water incidents in the KC-135

In conclusion, life rafts provide warmth, protection, and a platform to live after a traumatic event. As previously shown, life rafts have yet to be used on these military aircraft and not because there have not been any water impacts. The life raft employment system on the C-130 and KC-135 has shown to not be useful. Furthermore, the C-130 and KC-135 have also illustrated that its design is not successful in a water landing.

However unlikely a water event and life raft usage maybe, there is a large cost to sustaining this feature. The next section analyzes how the airline industry and military have made decisions to reduce costs by upgrading or removing equipment.

Airline and Military Aviation Cost Savings

The airline industry serves as a great example to the military in applying fuel-saving strategies. Individual airlines compete against one another for business in a capitalistic financial market and have increased incentive to employ the latest, most innovated, and timely cost-cutting strategies. Airlines have shown that minor changes' onboard aircraft can result in saving millions or even billions of dollars. For example, American Airlines reduced its weight by decreasing the potable water in the bathrooms commensurate with the needed amount not the maximum

(Frishling, 2012). American Airlines removed magazine racks, logo lights, shaver outlets, and sky phones in order to reduce weight saving over one million gallons of fuel (Frishling, 2012). They also upgraded current equipment, not because of functionality but weight, such as their catering carts saving over 1.8 million gallons of fuel (Frishling, 2012).

Other airlines have washed their aircraft in order to remove debris; United Airlines began this practice and estimated close to 12 million dollars in savings (Alcantara, 2008). American Airlines CEO Robert Crandall exemplifies the extent that airline personnel pursue cost-cutting measures. He ordered a study to analyze the cost savings of removing olives in the salads that they provided. The study concluded that the savings were in excess of 500 thousand dollars (Robinson, 1997). These are just a few of the ideas that the airlines adopted in order to cut costs, all relevant examples for the Air Force to follow.

While these strategies have focused on reducing weight of the aircraft, it is important to consider the weight of the fuel itself. Fuel accounts for the majority of weight on most aircraft. For example, a Boeing 767 max weight is 395,000 pounds and has 163,064 pounds of fuel capacity, making the fuel about 41% of total weight (Boeing, 2012). As a very basic example of how weight impacts fuel consumption: assume that every pound of matter requires a quarter pound of fuel for a particular flight. Carrying a 100-pound object onboard will require an additional 25 pounds of fuel for the duration of the flight. The added 25 pounds of fuel will need 6+ pounds to account for the initial amount of fuel. Therefore, to carry the 100-pound object, more than 31 pounds of fuel are required. Obviously, the actual calculation is much more complex, but this example demonstrates how even a small item requires exponential amounts of fuel.

Fuel represents about 30% of airlines operating budget and any chance to reduce the amount used results in large savings (Durham, 2011). Airlines currently plan for more fuel than needed if an unexpected contingency occurs. An in-flight emergency, weather deviation, and air-traffic control delay are some of the problems that may arise in a given flight. Due to these issues, airlines fly with a 10% reserve to avoid running out of fuel. As technology and services improve the airlines may be able to reduce this fuel reserve and save large amounts of money while maintaining a safe service. Some airlines are using InFlight, which provides instant advisories to the Flight Captain, who makes more efficient decisions, thus improving savings in fuel use (Durham, 2011). Another way to achieve fuel savings involves optimizing the way an aircraft is flown. Flying at favorable speeds and altitudes saves fuel. An aircraft has a max range for a given aircraft weight; this is why aircraft altitude change during a flight.

The fuel reduction strategies used by airlines do not come without consequences when the unexpected and extended delay occurs. From 2008 to 2010, 41 airline aircraft declared an emergency fuel situation (Millward, 2012). Many pilots are under pressure to ensure they do not carry extra fuel above what the regulated amount in order to save money (Millward, 2012). A retired pilot said, "he and his colleagues were under pressure from airlines because of the industry's need to keep costs down. There is pressure on pilots, by the airlines, to carry minimum fuel" (Millward, 2012:1).

The removal of olives from salads shows the detail in which airlines have looked at increasing their margins but hardly relates to the safety of the aircraft. However, reducing fuel to a point where it is more efficient does. This padding of fuel is a large safety feature that ensures the flexibility of options in a dynamic airline business that deals with delays and weather.

Airlines, along with regulatory bodies, have made decisions that balance this cost and flexibility, which provides a similar map for the Air Force and its operations.

Fuel Initiatives

The studies performed on the airlines indicate fuel conservation techniques can potentially save billions of dollars annually. The need for this study and others is paramount. For both the airline industry and the U.S. Air Force, fuel is the second highest reoccurring cost next to personnel. With a limited budget, both the civilian and military sector generally has two courses of action when faced with escalating fuel prices: 1) cut personnel expenses – including jobs, pensions, benefits; alternatively, 2) decrease fuel consumption. As history has shown, method #1 is the most readily available, and can disrupt thousands of lives.

United Airlines provides a great historical example of how airlines have reacted to increasing fuel prices. In the aftermath of the Persian Gulf crisis, oil prices hit record highs, and customers were lost to low-cost, no-frills competition (UAL website, 2008). Net losses came close to $1.0 billion, and management quickly began containing their costs (UAL website, 2008). A hiring freeze, grounding of older aircraft, and renegotiating employee salaries reduced their expense enough to where they were once again profitable (UAL website, 2008). Then following the tragedy of September 11th, United Airlines lost billions of dollars due to decreased demand for air travel (UAL, 2008). United furloughed 20,000 employees and cut back 20% of its worldwide travel (Findlaw, 2008). Most recently, trade unions reduced their salaries by $5 billion, and marketing and advertising reduced expenditures by $60 million to cope with escalating fuel prices (Johannes, 2006). United Airlines has already slashed non-profitable domestic routes by 20% and retired 94 of its Boeing 737s and 6 of its 747s (De Lollis, 2008).

In many ways, the Air Force is not unlike the airlines. As stated previously, approximately 40,000 Air Force jobs were recently eliminated to ease the organizations bottom-line. The Air Force must become more efficient with the use of its money, or else future budget cuts will continue to negatively affect thousands of Airmen. Military benefits, pensions, jobs and mission effectiveness may all be in jeopardy if immediate cost-efficiency programs are not installed. All airframes must be intensely analyzed, and when possible, budget savings should be realized from positive efforts – such as fuel efficiency – rather than cuts to personnel and benefit programs. The Fiscal Year 2012 Operational Energy Budget Certification Report speaks about the importance of the Department of Defense to ensure a reliable source of energy, mitigate the supply disruptions due to the growing global demand for oil and ensure a complete understanding of the geo strategic impact to our national security (OE Budget Report, 2012). In this report, the Air Force plans to make a 10% reduction in fuel consumption by 2015 (OE Budget Report, 2012).

A reduction in fuel consumption may occur due to changes in the mission and training requirements, or it may occur through increased vigilance in planning, training, and modifying our aircraft flights to fit a more efficient set of standards. There are many ways to save fuel, and one small effort may come in the form of reducing the weight on board the aircraft in order to begin to meet the objective of reduced fuel consumption regardless of future mission requirements. For every dollar increase in the price of a barrel of oil, the DoD incurs an additional $130 million in fuel costs a year (Medici, 2012). From fiscal year 2005 to fiscal year 2011 DoD's petroleum use decreased by 4 percent but the spending rose 381 percent in real inflation-adjusted terms (US DoD Energy Initiatives Report, 2012).

Sharon Burke, assistant secretary of Defense for Operational Energy Plans and Programs, stated that Air Mobility Command has investigated numerous weight-reduction initiatives across all platforms that could to save over $500 million in the next 5 years (Medici, 2012).

Because fuel is the second greatest component of the Air Force budget, it is imperative that aircraft efficiency is continually improved and evaluated. Furthermore, "the Air Force is the largest user of energy in the Department of Defense and aviation operations account for 79% of that energy usage. Of that, over half is attributable to air mobility operations" (AMC FEO Strategy, 2012:6). During the fiscal year of 2011, 64% of Air Force aviation fuel was used for mobility, and logistics air operations (US DoD Energy Initiatives Report, 2012).

Air Mobility Command (AMC) created the Fuel-Efficiency Office (FEO), specifically in order to transform the way energy is used so that America can lead the way in building a clean-energy economy (AMC FEO Strategy, 2012). The FEO office continues by stating that "failure to make significant and timely adjustments will weaken our security" (AMC FEO Strategy, 2012:3). The FEO office has followed the airlines in reducing fuel consumption by improving efficiency in the C-5, C-17, C-130, KC-10 and KC-135. AMC has a more dynamic mission than that of the Airlines, mainly in part due to the nature of war. Efficiency is important but effectiveness trumps when it comes to sustaining lives and providing the Combatant Commanders support to fight the war (AMC FEO Strategy, 2012). The AMC FEO Strategy guides further states

> *Effectiveness in Mobility Air Force (MAF) operations must remain paramount; supporting those who depend on us is our first priority. We must also be good stewards of our nation's resources. Our operations must be as efficient as effectiveness allows, delivering the right effects, at the right place, at the right time. From that perspective, fuel efficiency measures must be fully integrated into air mobility planning, support processes, and mission execution activities.* (AMC FEO Strategy, 2013:6)

Leveraging technology, effective flight planning, cargo load planning, maintenance activities, fuel efficient aircraft systems, command and control and increasing the knowledge of Airmen are all part of the FEO approach to reduce fuel consumption (AMC Fuel Strategy, 2012). Decreasing fuel consumption usually entails one of two concepts, losing capability by removing equipment or by investing capital improving efficiency. The next section entails how AMC has accomplished both methods in the C-5, C-17, C-130, KC-10, and KC-135.

C-5

Recently, the AMC FEO personnel investigated numerous weight reduction initiatives across all of its platforms. The C-5 is the largest aircraft in Air Mobility Command both in weight and size.

When equipment is removed from the aircraft, the weight is reduced and the aircraft will burn less weight per hour of flight. The fuel savings from removing this equipment off of the C-5 is computed based upon a study in 2008 completed by Cyintech (Figure 30). In 2008, Cyintech measured the fuel used on 63 C-5 flights and ran a linear regression to find an average fuel burn cost of 5.67% (Cyintech, 2008). This means that for every 100 pounds of equipment carried, 5.67 pounds of fuel are burned per hour of flight (Cyintech, 2008).

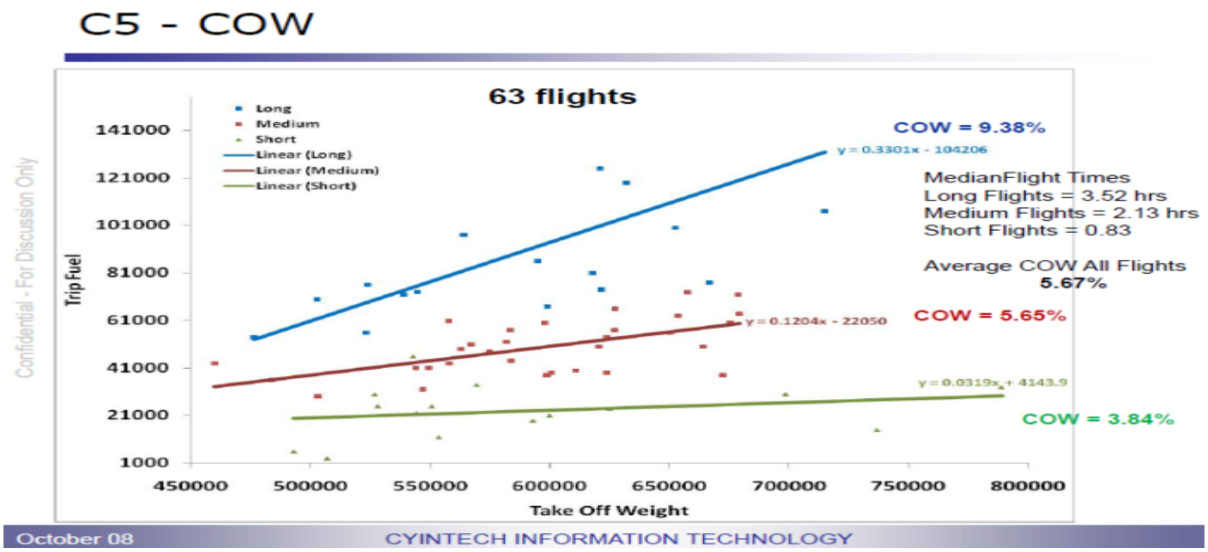


Figure 30. C-5 Cost of Weight. (Cyintech, 2008)

Some of the initiatives that are currently in place to reduce weight on a C-5 are removal of: 1) Weight and Balance Computer, 2) Protective Armor, 3) Water Storage Tanks, 4) Potable Water Tank, 5) Low Pressure Pneumatic System (Figure 31) (AMC C-5, 2012).

TCTO Number	SYSTEM	Unit Wt (lb.)	C-5A	C-5B	C-5C	C-5M	Man Hours
1C-5-857	Weight & Balance Computer	25	✓	✗	✗	✗	3
1C-5-883	Protective Armor	210	✓	✓	✓	✓	10
1C-5-887	Water Storage Tanks	154	✓	✗	✗	✗	20
1C-5-888	Potable Water Tank	100	✗	✓	✗	✓	20
1C-5-891	Low Pressure Pneumatic System	75	✓	✓	✓	✓	6
			27	35	2	15	

Quantity of Aircraft Impacted (AMC C-5, 2012)

Figure 31. Quantity of Aircraft Impacted (AMC C-5, 2012)

Within the first year of removal, the FEO office expects 56,869 gallons of fuel saved resulting in cost savings of $218,945 (AMC FEO, C-5). Within 5 years, due to TCTO compliance, the Air Force expects a total saving of $1,458,044 (AMC FEO, C-5). AMC has also decided to remove additional equipment that includes frozen-food service equipment, troop oven, troop refrigerator, winch, and coffee unit that total to 831 pounds for the C-5A, 831 pounds for

the C-5B and C-5M, and 359 pounds for the C-5C (AMC FEO, C-5). The flight hours for the C-5 for fiscal year 2013 are programmed to be 31,994 (FEO, 2013).

If 385 pounds were removed from the C-5, it would save 22 pounds or 3.23 gallons of fuel per hour (FEO, 2013). Based on the forecasted flight hours the total fuel saving for 2013 is 103,315 gallons or about $385,367 at $3.73 per gallon of JP-8. The removal of the items is mainly crew comfort or non-essential aircraft equipment. The protective armor was removed and was considered to be additional armor that was not necessary for the mission. This calculation was based on cost and the acceptance of increased risk.

Based on the current fleet and expected flight hours per fiscal year, the C-5 will save $1,014 for every pound it removes from each aircraft for the fiscal year of 2013 (AMC FEO, C-5).

C-17

Cyintech calculated the C-17 cost of weight at an average of 4.4% (Figure 32) (Cyintech, 2008). As noted before, this means that for every 100 pounds carried the C-17 will burn an extra 4.4 pounds of fuel per flight hour.

The FEO has also reduced the weight of the C-17 by removing parachutes, survival vests, aircrew body armor and ML-4 survival kits (AMC FEO, 2013). All of these items deal directly with the aircrew safety. They were deemed not to meet the utility standards for the cost that was incurred to maintain this capability. The total weight of removing this equipment was 132 pounds (Addenda A Pub: 2010).

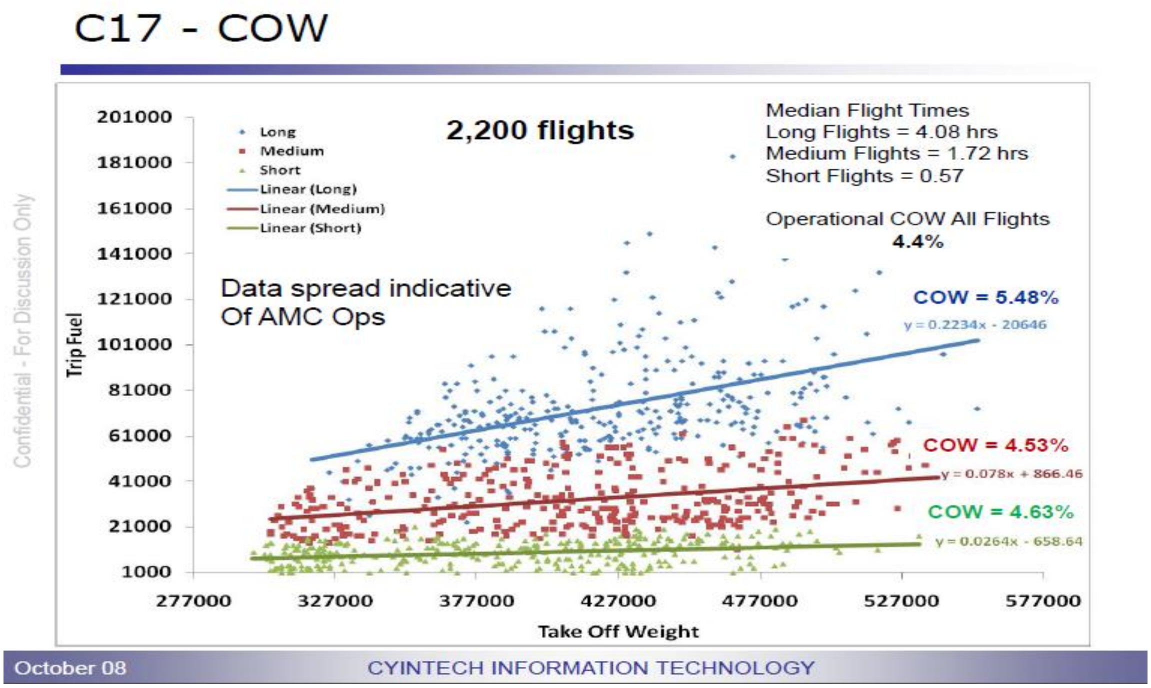


Figure 32. C-17 COW, (Cyintech, 2008)

The program hours for the C-17 in 2013 are estimated to be 175,124 hours (AMC FEO, 2013). The cost of weight saved by removing 132 pounds will gain six pounds of fuel per flight hour or .86 gallons. This will net a total of 150,461 gallons of fuel or $482,185 of savings at a cost of $3.73 per gallon of JP8 (AMC FEO, 2013). The C-17 will save approximately $4,251 in 2013 for every 1 pound it removes from each aircraft for the C-17 fleet (AMC FEO, 2013). Due to the significant number of flight hours, the C-17 saves about four times the amount of money for every pound removed compared to the C-5.

C-130

Cyintech did not calculate the cost of weight for the C-130, but the FEO office uses a conservative 3% when calculating fuel savings for the C-130 (AMC FEO, 2010). The C-130J

models may remove 825 pounds, and the C130E/H models may remove, 1,064 pounds for local flights (AMC FEO, 2010).

The C-130E/H model also permanently removed Ma-1 wheeled pry bars, liquid containers, and truck loading ramps reducing the total weight by 288 pounds and fuel consumption by 1.28 gallons per hour of flight (AMC FEO, 2010). C-130J model carries the same equipment and will remove it once the contract is completed in 2013 (AMC FEO, 2013). If the equipment was removed from the aircraft, savings of approximately 179,000 pounds of fuel or $667,000 would be realized based on the 140,039 projected hours for 2013 (FEO, 2013).

The C-130 can remove up to 1,064 pounds by removing equipment for local flights. The amount of fuel saved depends on the total time that it is removed but could save around $1,250,000 based on removing the equipment for about 50% of the time that the aircraft is flown. For the next year, AMC can save $2,280 for every pound that is removed from each C-130 aircraft.

KC-10

The KC-10 has an average cost of weight of 4.47% (Figure 33) (Cyintech, 2008). Similar to the C-130, the KC-10 may remove some equipment permanently and other equipment based on local missions. The KC-10 has permanently removed the EPOS Boxes that weighed 393 pounds and will save 17.6 pounds or 2.62 gallons per flight hour.

The KC-10 is expected to fly 39,405 hours for 2013 (AMC FEO, 2013). The total savings for removing the EPOS Boxes is 103,318 gallons of fuel or $390,540. The KC-10 may remove equipment for local flights, which totals to 6,162 pounds (Figure 34) (AMC FEO, 2010).

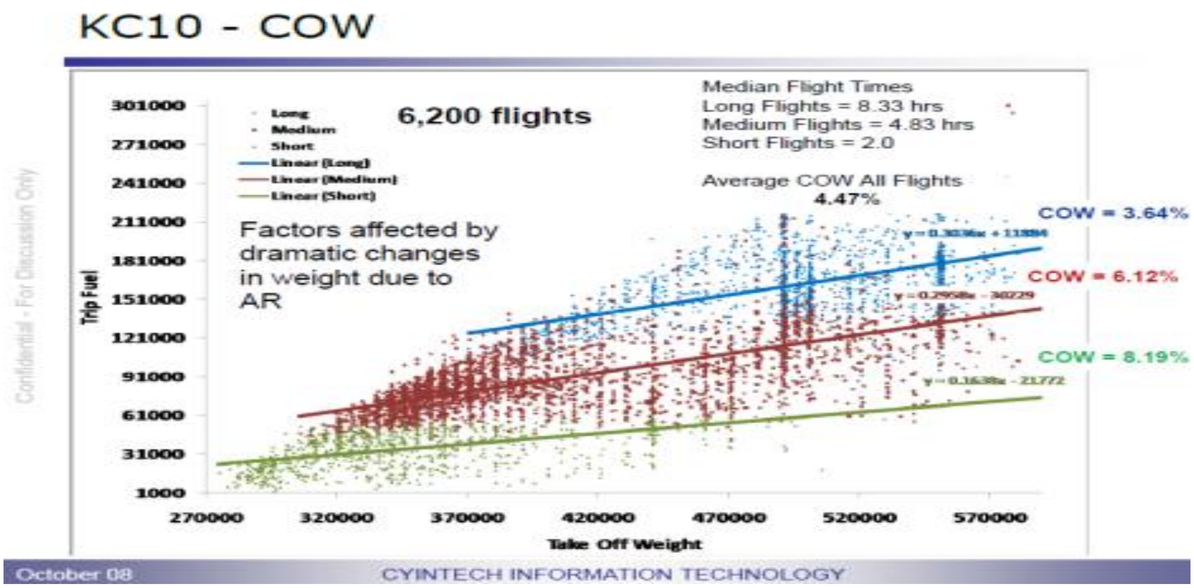


Figure 33. KC-10 COW, (Cyintech, 2008)

Once again, the savings can vary widely based on how many localized flights are conducted and how often these aircraft can maintain flights without needing this equipment. If one assumed that flights were conducted without this equipment for 50% to 100 % of the time the savings would be \$809,982 and \$6,123,469 respectively. For every pound that is removed from the KC-10 fleet for the year results in savings of \$993.75 (AMC FEO, 2013).

QTY	Items Removed For Locals	Weight
4	Survival Vests	66
4	Body Armor	55
4	LPU 10/P	14
4	AERP Hose kit	40
4	Infant Cots	20
4	Anti-Exposure Suits	25
1	Passenger Demo Kit	3
4	Mil-G-635	4
	IAU Seat Pallets	3200
1	JAATT Box	985
	Pallet 13L/Pallet Subfloor	290
1	Vacuum Cleaner	32
1	Cargo Winch	89
1	Crew Chief Onboard Parts Kit	16
1	Ground Wires (50 ft)	0
1	Sill Protector, Cargo Door	118
1	Mop	3
1	Broom Push	2
1	Broom Swish	2
12	Passenger Service Trays	18
1	Dust Pan	2
30	MB-1 Tie Down Chain	210
20	CGU-1B Tie-Down Strap	80
30	MB-1 tTension Device	105
1	Potable Water	700
1	Extended Ladder Assembly	83
	TOTAL Weight Removed	6162

Figure 34. KC-10 Removable Items (FEO, 2013)

KC-135

Cyintech concluded that the average cost of weight on a KC-135 was 4.97% (Figure 35) (Cyintech, 2008). The KC-135 fleet saved money through removing equipment based upon the mission requirements. This is different than the previous platforms mentioned because it means that equipment removed is stored in an appropriate facility so it can be reinstalled for future use.

This requires extra handling of equipment, more storage capacities, and a decrease in mission flexibility.

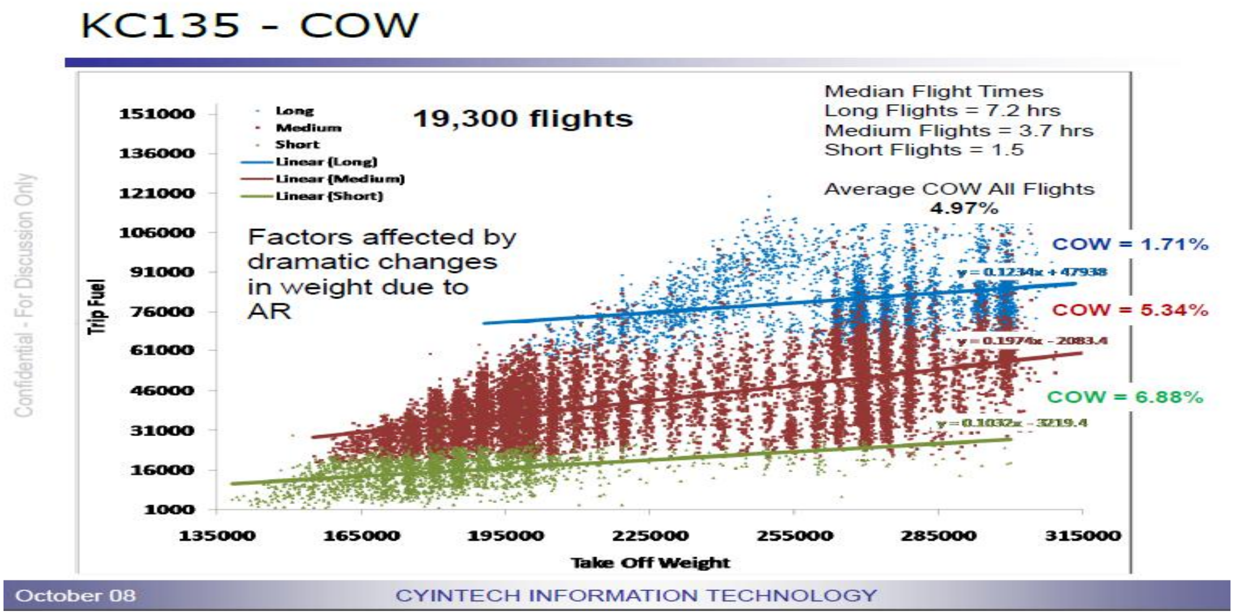


Figure 35. KC-135 COW, (Cyintech, 2008)

The KC-135 has removed equipment based on local requirements and if the unit is an Active duty or Guard/Reserve unit (Figures 36 and 37) (AMC FEO, 2010). The equipment that is removed for the respective unit and the total weight totals to approximately 3,500 pounds. The active-duty KC-135 fleet could see savings of $35 per hour by removing the 1,297 pounds. The fleet is expected to fly a total of 42,714 hours for fiscal year 2013 that will amount to an annual saving of approximately $1,500,000 (AMC FEO, 2013).

The KC-135 guard and reserve fleet will save up to 113.8 pounds per hour by removing 2,289 pounds of equipment. About 17 gallons are saved by removing this weight that amounts to about $64.18 per hour when JP-8 costs $3.73 per gallon.

QTY	AFRC/ANG	Weight
	Items Removed For Locals	
	exposure suits	21
4	parachutes/seat kit	202
2	airline seats	140
3	baggage bins	852
40	EPOS	83
40	LPUs	80
2	Life Rafts	310
4	Body Armor/Surv vest/storage kit	110
1	HAZMAT Spill Kits	36
	Excess tiedown devices	378
2	Excess Oil and Hydro	60
	infant cots	17
	TOTAL Weight Removed	2289

Figure 36. KC-135 Reserve and Guard Removable Items (FEO, 2013).

QTY	AD	weight
	Items Removed For Locals	
	exposure suits	21
4	parachutes/seat kit	202
40	EPOS	83
40	LPUs	80
2	Life Rafts	310
4	Body Armor/Surv vest/ storage kit	110
1	HAZMAT Spill Kits	36
	Excess tiedown devices	378
2	Excess Oil and Hydro	60
	infant cots	17

Figure 37. KC-135 Active Duty Removable Items (FEO, 2013)

The total expected flight hours for the KC-135 guard and reserve fleet is 70,548 hours that would amount to total savings of $4,428,422 (AMC FEO, 2013). The savings per annum do not calculate the man-hours spent on removing and replacing this equipment for local flights and assume that the equipment would be removed for the entire year (AMC FEO, 2013). If the KC-135 fleet removes one additional pound of weight for the year, the savings would be $3,106 per pound (AMC FEO, 2013).

In summary, the AMC FEO office has made significant strides in reducing the weight on the C-5, C-17, C-130, KC-10, and KC-135. The C-17, based on flight hours and the Cyintech study will save the most money by removing weight followed by the KC-135, C-130, C-5, and KC-10. However, the C-130 could realize more savings in the event that the conservative 3% is actually more.

This historical analysis illustrates the decisions made to remove certain equipment, including safety equipment like parachutes. These decisions have saved money while losing little capability. However, analyzing the removal of life rafts and the savings is not a complete examination. Much debate and discussion occur with these decisions to remove equipment or invest in upgraded equipment. This is why this study needs to examine the many other aspects than just the money, which is done with a Delphi Study.

Delphi Method on Disaster Relief

Aircraft ditching events are very rare, and as previously shown the ability to use the large life rafts has yet to occur on the airframes in this study. Because of this scarcity of data, it is critical to solicit the opinions of experts. A Delphi Study provides this capability. Next, an

example of a Delphi Study illustrates the utility of this method when trying to better understand a situation when information is limited with emergency preparedness.

In 1970, a Delphi study was conducted by the office of Emergency Preparedness and the Rand Corporation on the subject of Civil Defense Policy (Linstone & Turoff, 1975). This study introduced a number of issues that involved strong disagreement among those on the panel (Linstone & Turoff, 1975). In this study, the sponsor wanted the group to develop, compare, and evaluate the best possible arguments on each side of the issue (Linstone & Turoff, 1975). The level at which Federal, State, and Local agencies integrate share and practice the same procedures of preparedness was the core issue of this Delphi Study (Linstone & Turoff, 1975). Furthermore, the Delphi study was used to explore underlying assumptions from panel members in different departments, understand the core issues, and to lead to new knowledge in the area of Civil Defense Policy (Linstone & Turoff, 1975).

This Delphi study introduced a number of new features such as the structure of the Hegelian inquiring system (Linstone & Turoff, 1975). This method assumes that people do not have the absolute answer but rather an answer that is based on their cultural and historical knowledge (Linstone & Turoff, 1975). This system, given the large pool of participants, enabled a large assortment of information and data regarding the ability for each agency to provide and prepare for large disasters (Linstone & Turoff, 1975).

Members were allowed to pick simple answers such as “should, should not” or “could, could not” and elaborate on their responses (Linstone & Turoff, 1975). This allowed the sponsor to receive information regarding Civil Defense that directed the members from a panel to conclusive arguments (Linstone & Turoff, 1975). In addition, this Delphi addressed policy options based on scales of desirability and feasibility (Linstone & Turoff, 1975). The simple

questions proved to be extremely useful for this study and allowed for a structured debating-type format that is very helpful to a policy issue (Linstone & Turoff, 1975).

In summary, the history of aviation has shown that decisions are continually made to either improve or remove equipment based on a changing cost-benefit analysis. Furthermore, the benefit is sometimes misunderstood because of the rarity of an event. An analysis of the risk, cost, and effect of the possible removal of life rafts is important to providing top AMC leaders the knowledge needed to make critical decisions.

III. Methodology

There are two critical components to this study on large life rafts: 1) An analysis on how often the C-5, C-17, C-130, KC-10, KC-135 fly with passengers over water, 2) A Delphi Study in order to better understand the policy of life rafts and the implications of changing that policy.

Analysis

An analysis of flights from the aircraft in this study has yet to be accomplished and is critical to understanding the actual risk and policy for which the aircraft is governed. The FAA mandates that life rafts are only needed when operating under extended over water policy. Thereby, a reasonable assumption is that an aircraft can remove the equipment needed by this policy when the aircraft is operating over land or near land as to not violate the rules. In addition, aircraft not carrying passengers do not need life rafts based upon the FAA policy.

Removing life rafts on missions that do not require them would save fuel but would require extensive labor, logistics capabilities, and a loss in flexibility. Nevertheless, if policy makers are unaware of how often flights occur with passengers over water, how can an informed decision be made?

This analysis answers these questions by evaluating 393,103 flights since October 2009, for the C-5, C-17, C-130, KC-10, and KC-135. This data was gathered from G2 operating system that is used by AMC. The data is filtered based on the aircraft, passengers, departure location, and arrival location. These flights are then be grouped into their respective categories and subsequent flights between the same airports are counted.

Once this is completed using excel programming, it is filtered using KML programming code to show on Google Earth. This is important to display so that each combination can be

viewed and then filtered based on if it flies over water. Unfortunately, there was not a way that could automatically depict whether the flight was over water other than using the overlay feature and ensuring that the flight path exceeds 50 miles from the land on Google Earth.

The flights are then be grouped into over water flights and non-over water flights where they are filtered back into Excel as carrying passengers or not. Once this is completed, the data will indicate how many flights are over water, with and without passengers. For example, if a C-5 flight was from Dover to Ramstein with passengers, the flight would be categorized as an over water passenger flight with passengers. Furthermore, if this flight occurred again than the flight count would equal two.

The cost of ferrying life rafts has been computed on an annual scale for the KC-135 but not for the other aircraft in this study. In addition to calculating the cost on an annual basis this study also includes the cost of life rafts for the entire employment life time on these aircraft. In order to accomplish this, there are a four items that are needed: 1) The weight of the life rafts, containers, age kits, CO_2 canisters, and water survivor kits, 2) Cost of Weight (COW) calculations provided by Cyintech, 3) Total flying hours for the fleet and expected flying hours, and 4) Cost of fuel. Although fuel prices have changed since these aircraft were commissioned it is assumed that the cost of fuel has changed only due to inflation and therefore, the current price set by DLA is adequate in estimating a total cost of ferrying life rafts.

Delphi

The Delphi method is important for this study because it pulls knowledgeable opinions from subject matter experts regarding the employment of large life rafts. These views and opinions help formulate the direction in this study. The Delphi method is important because it

allows for a discussion among many experts in different fields to shape future policy upon complex decisions.

The Delphi method was developed in the 1950s in order to forecast the impact of technology on warfare and began at RAND, the "think tank" (Gordon, 1994). The forecasting approaches used were quite limited due to simulation capabilities (Gordon, 1994). During these limited simulations, experts would act out the part of the different parties in order to gain insight on possible future actions and outcomes of conflict, thus, providing a base in which decision makers could act upon (Gordon, 1994). As this method developed, the simulation gave way to an expert panel that would ultimately forecast outcomes of complex problems (Gordon, 1994). Through many simulations, experts realized that the group's decision was always better than the individuals (Gordon, 1994). More insight was gained to solve the complex problem by bringing in a multitude of experts (Gordon, 1994). Gibson wrote that "a complicated problem requires employees with diverse talents and functional expertise (Gibson, 2012).

However, the studies found that the experts did not regularly voice their opinions because the environment was not always conducive to gaining everyone's perspective on the issue (Gordon, 1994). In essence, the loudest individual may lead the expert panel to agree to a decision because of his or her power instead of clear logic from the group. "Group Conflict" and "Group Think" can negatively impact the experts when meeting together to discuss the solutions to these complex problems (Gibson, 2012). The Delphi process became more refined by removing this conflict and the biasing effects that may occur during in person interactions (Gibson, 2012). Soliciting the responses from experts through a medium such as mail, allows them to independently generate their responses (Gibson, 2012). The Delphi method "was

designed to be a true debate, independent of personalities" to avoid the personal conflicts (Gordon, 1994).

There are four individual phases during the Delphi process. The first phase explores the subject being researched, giving participants the opportunity to contribute information they feel is appropriate. The second phase moves to determine an understanding of how the entire group views the issue. If significant disagreement is determined, the third phase is used to explore that disagreement and ascertain reasons for differences. The fourth phase is a final evaluation of all gathered information (Linstone & Turoff, 1975).

A Delphi is an iterative process in which each process is built upon the previous one (Somerville, 2008). The Delphi method provides quantitative and qualitative results that are steered by the group (Cuhls, 2013). Anonymity and feedback represent the two aspects that are critical to the Delphi method (Gordon, 1994). As results are provided back to the expert panel, they gain insight on the group's answers but do not know their position or names (Gordon, 1994). Anonymity of panelists increases the probability that they will answer the questions objectively and is less influenced by the group (Somerville, 2008). As each round is concluded, the group will either get closer to a consensus on the answers to state why their belief is valid and different from the group's belief (Somerville, 2008). The outliers, or responses, that are outside the convergence of opinions or consensus will provide feedback or amend their answer (Sackman, 1974).

The Delphi method also provides the ability to debate while physically separated. Somerville states that the "advantage of the Delphi method is that is can gather information from a geographically diverse panel of participants" (Somerville, 2008:2). As technology has increased the velocity of information has also increased the capability of the Delphi method.

Utilizing a Delphi may also lead to changes in the opinion of panel members even though they are separated. There are two different types of unique phenomena that may occur: 1) The exercise starts with disagreement on a topic and ends with agreement, and 2) The panel starts with agreement and ends with disagreement (Linstone & Turoff, 1975). This occurs because of the solitary properties of a Delphi Study that provides the time, group-though process, and additional information that may lead panels to become more "educated" on the topic (Linstone & Turoff, 1975).

The Delphi method does come with disadvantages. When the Delphi method was introduced, the time and expense of designing the questionnaires, mailing, and follow-up mailings due to mistakes or survey's not complete were previous disadvantages to the Delphi method that have recently changed due to technology (Somerville, 2008). In addition, the time that the Delphi method takes, especially on the first iteration, can be discouraging to the participants, and they may not complete the survey (Somerville, 2008). This may result in a high-dropout rate (Somerville, 2008). The span of time that the study takes may discourage members on the panel, or they may become unavailable (Hsu, 2007).

Studies have also found that when participants are taking questionnaires individually versus working as a group, their level of participation and effort to the study may greatly change (Gibson, 2012). Furthermore, the Delphi method does not have a clear standard for establishing experts (Somerville, 2008). Critics have also stated that the Delphi method does not provide the same starting point for all members and promotes quick answers instead of lengthy debate (Somerville, 2008). This leads to members conforming to complex problems versus reaching consensus (Somerville, 2008).

The Delphi panel size is critical in the study's success. The panel should generally be under 50 and 15-20 members are the norm (Hsu, 2007). The size of the Delphi varies from topic to topic, but the research should always keep in mind that when a group is too large, it may lead to low response rates due to the span of time the study takes. In addition to weak response rate, information overload can occur, leading to poor performance on the answers (Hsu, 2007). A team size of 15 form homogenous panels and 5 to 10 experts are preferred for heterogeneous groups (Sommerville, 2008).

There are many steps in the Delphi Method. Once a topic is picked, and a steering team is in place it is important to find an expert panel (Cuhls, 2013). First, the design-monitor team should be at least two people in order for them to check one another (Linstone & Turoff, 1975).

The panel is critical to the Delphi method because the accuracy of the study depends on the panel's knowledge and understanding within the field in question (Somerville, 2008). The expert panel may also provide better accuracy if they come from diverse fields that deal with the given study (Somerville, 2008). This diversity brings insights into the debate that might otherwise be missed by a homogenous group. Picking the right panel may also lead to higher return rate because the individuals are highly competent in the area of research instead of random selection (Dobbins, 2004). It is also important to figure out the panel size. As previously mentioned there are pros and cons to larger or smaller panels.

In addition to picking the right size, the group must be convinced that participation is amongst peers on the subject (Linstone & Turoff, 1975). This is important to receive buy-in from the experts, but it is important that there is not too much information as to identify the members because it may bias opinion’s and hinders confidentiality (Linstone & Turoff, 1975).

After a panel is established, the facilitator introduces a list of open-ended questions and distributes them to the panel. The facilitator either needs to be an expert or have an expert to ensure that the panel members do not become teachers during the Delphi study but rather provide new information to the field (Linstone & Turoff, 1975). The questions need to be concise and answerable (Gordon, 1994). The questions should be simple statements that are not compounded (Linstone & Turoff, 1975). In addition, the questionnaire needs to be pretested on others to ensure that it is not confusing or misleading (Linstone & Turoff, 1975). An example of a question is “What do you believe were the driving factors for putting large life rafts on board the KC-135, C-17, KC-10, C-5, or C-130?” Open-ended questions are critical to revealing the direction that the panel deems significant.

If the panel is initially asked questions that do not allow them to expand upon answers it may limit the study, thus missing important factors. Once these questions are ready and vetted they should be sent to the panel with a specific cover letter establishing the objectives, schedule, rules of engagement, and elaborate on the Delphi rules (Gordon, 1994). Gordon states that the response rate is usually around 40-75% and ordinarily takes a few weeks to receive the answers (Gordon, 1994).

Once the results are gathered, the facilitator collects and summarizes. The answers of the panel are then categorized (Lindstone, 2002). Sometimes, during a Policy Delphi Study, many new ideas may come up during the discussion because the underlying assumptions and arguments are questioned (Linstone & Turoff, 1975).

The number or frequency that a certain subject is discussed from round one formulates the topics for the second round (Lindstone, 2002). This is the largest single task in the Delphi study and also tends to have the greatest error (Lindstone, 2002). Since the questions are open-

ended, there is a wide array of information. This information needs to be sorted and quantified. There are also answers that may open other discussion topics, which were not previously mentioned in the studies and are very relevant (Lindstone, 2002).

After examining the results and ensuring the facilitator accurately assessed the answers of the panel, the facilitator will develop round two. The questions are developed from the responses of the first round based on how the entire group views the issues (Dobbins, 2004). While conducting a Policy Delphi study, the amount of written material generated maybe significant especially when respondents feel strongly about an issue (Linstone & Turoff, 1975). From this point, the answers are carefully separated into similar themes (Linstone & Turoff, 1975).

In a three-round Policy Delphi Study, the second round usually comprises of questions that are asked to the panel that can be measured quantitatively or qualitatively (Linstone & Turoff, 1975).

Questions are often times quantified through using a Likert Scale, rank order system, or some other means where the data can be collated (Dobbins, 2004). The Likert Scale is important to round two of the Delphi method because it provides the facilitator a means to quantify measure responses of the panel. The Likert scale is used in questionnaires to gather the panel's preferences or degree of agreement with a particular statement. The Likert scale is most often seen as a five-point scale, similar to the one in Figure 38 (Bertram, 2007). There are many variations to this scale that allow the facilitator the freedom to pick larger scales in order for additional granularity (Bertram, 2007). The Likert scale is used because it is simple to construct, easy for the panel, and likely to produce reliable results (Bertram, 2007).

Figure 38. Likert Scale Example, (Dobbins, 2004)

On the other hand, when the Likert scale is used it may show central tendency bias, which is when the participants avoid extreme responses (Betram, 2007). An ordinal scale is also used in the Delphi method and offers a different perspective than that of the Likert Scale. It is a ranking of information that can clearly delineate answers. This provides greater fidelity to the study, but when used alone it provides no magnitude to the differences (Bertram, 2008).

The evaluation of answers from the panel to indicate agreement or consensus can be done using many different measures such as: bar charts, dot plots, statistical like median mode, and inter-quartile range (Bertram, 2008).

Once the questions are validated and tested, they are then sent to the panel and later recollected. There are many different methods that can be used in order to ascertain group consensus or to better understand the opinions of the panel. Likert or ordinal values lend themselves to ascertain the average, standard deviation, convergence, normality, quartile, independence, one- or two-tailed tests, and many other types of statistical analysis (Bertram, 2008).

Once the data is analyzed, it can then be presented back to the panel in which they can provide further information on why their answers are either different or similar to the group's responses. This revote of information allows all members to view the answers from the group and provide analysis, remarks, and exercise a revote (Linstone & Turoff, 1975).

The Policy Delphi is an organized method for correlating views, exploring underlying assumptions, and to voice opinion's on others points in a confidential manner (Linstone & Turoff, 1975). Respondents are anonymous, ensuring that they are free from embarrassment, repercussions, and removed from dominating personalities (Linstone & Turoff, 1975). The Delphi study explores all options for consideration, estimates the impact on policy, and examines the future acceptability of policy changes (Linstone & Turoff, 1975).

The Policy Delphi method is critical for this analysis. A team of experts, in different fields, will provide new information on safety policy relating to the use of large life rafts on the C-5, C-17, C-130, KC-10, and KC-135.

Extensive work was conducted with the sponsor to develop the right team for this study. Subject matter experts in a wide array of fields are important for this study. Members were chosen based on their experiences with safety, command, public affairs, regulatory and monetary policy, and life rafts on board the aircraft in this study. The subject matter experts were chosen from the following categories: 1) Safety, 2) Operations, 3) Maintenance, 4) Air Force Policy, 4) FAA policy, 5) NTSB ditching analysis, 6) Aircrew flight equipment, 7) Aircrew, 8) Wing, Group, and Squadron commanders, 9) Numbered Air Force commander, 10) Chaplain, 11) Fuel efficiency, and 12) Public Affairs. All of the panel members were either a chief or commander of their respective position.

- The expert panel had extensive experience within AMC and leadership roles.
- Air Force Safety Chief
- Wing Command
- Chief Safety Division, MAJCOM
- Chief Maintenance Division, MAJCOM
- Fuel Efficiency Office Operations Analyst, MAJCOM
- Chairman, Equipped to Survive Foundation
- Director, Public Affairs, Numbered Air Force

- Chief, Programs Division, MAJCOM
- Inflight Senior Director, Major Airline
- Director of Safety, MAJCOM
- Group Commander
- Squadron Commander
- Chief, Investigations Team HQ
- Chief, Stan/Eval MAJCOM
- Chaplain
- Structures and Mechanical Systems Engineer
- FAA Policy Director
- NTSB Office of Safety, Survival Factors Investigator

In summary, the methodology used in this study combines a Delphi Study, for the qualitative aspect, and an analysis on flight data and costs, to better understand the qualitative aspect, of large life rafts on the C-5, C-17, C-130, KC-10, and KC-135. The next section discusses these results and findings from both of the two approaches.

IV. Results and Analysis

Analysis Results

The analysis was extremely extensive and time consuming, but provides information to the community that has yet to be seen. In this next section, a breakdown of each aircraft and its respective flights since October 2009 until March of 2013 were examined and depicted on Google Earth. The pictures only show the flights that carried passengers. If the primary mission changed to the Pacific, that data also depicts common routes and percent of flights over-water for that specific region. This translates to an increased percentage of flights that are subject to life rafts. For this analysis, it is assumed that extra aircrew members of the flight would show up under passengers and thus be accounted for when considering life rafts.

C-5

The C-5 flew 17,947 missions since October of 2009 until March 2013. Out of all these sorties, 60% of the time the aircraft did not carry passengers (Figure 39). The range of passengers is important because it determines the number of life rafts required. The quantity of life rafts needed per FAA are based on 150% of the passenger load, and since the C-5 has four 25-man life rafts that are capable of holding 31 passengers each totaling to a capacity of 124 or 155% percent of the max capacity of 80 passengers (FAA, 2013: C-5 Fact Sheet, 2011). Thus, 31% of the flights carried passenger loads that ranged from one to 20, 6% of flights carried 21 to 40 passengers, and 6% of flights carried more than 41 passengers.

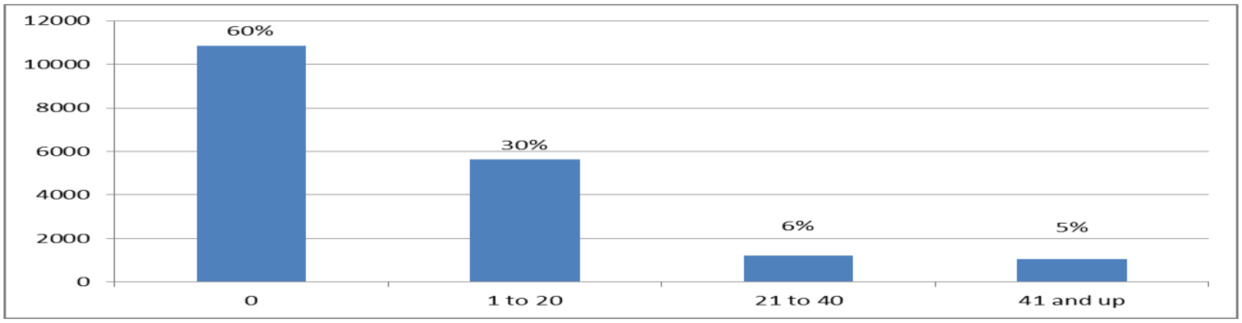


Figure 39. C-5 Flights with Passengers

Flying passengers does not necessitate carrying life rafts; however it does when they are flown over water (Figure 40). Of the flights that carried passengers, 61% of the time the flight traversed at least 50 miles from the shore, where 39% of the flights did not cross more than 50 miles per FAA EOW regulations.

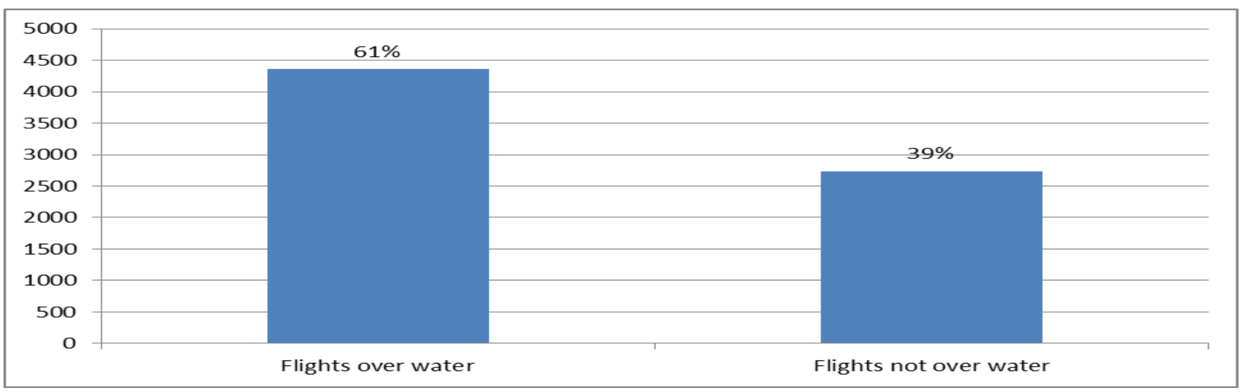


Figure 40. C-5 Flights with Passengers Flown Over Water

In total 24% of all flights carried passengers and traversed over the water (Figure 41). Life raft requirements by the FAA also stipulate that if the primary raft were to be unusable, a back-up raft is available. Due to this stipulation, the following results adhere to the FAA: 0 rafts are needed on 76% of all flights, 2 rafts would be needed on 21% of the flights, and at least 3 rafts would be needed for less than 3% of all flights.

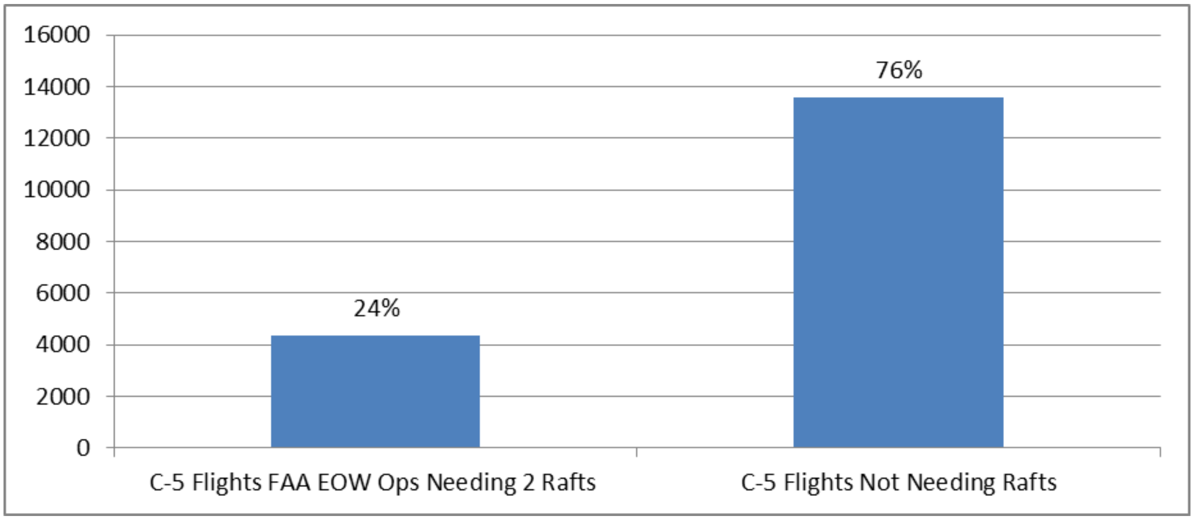


Figure 41. C-5 Flights Needing Life Rafts

The flights are also depicted on Google earth (Appendix D, C-5) to illustrate the general flight pattern and a visual representation of flights with passengers. The white lines represent flights that are not flown more than 50 miles from water and carry passengers, and the red lines represent flights flown over water and carry passengers. Each line is indicative of a flight from an airport to another airport but it does not provide the total number of flights that occurred between those two airports. In order to show both flights over water and numerous arrival destination combos a table was created for those combinations that numbered over 50 (Figure 42). These flights are only including those with passengers and are not the most significant flight profile. For example, there were 851 flights that originated and landed at Dover Air Field as a local training sortie.

Count of Flights	Total Passengers	Average Passenger	Name
339	7339	21.65	KDOV-LERT
331	5794	17.50	LERT-KDOV
169	4737	28.03	ETAR-KDOV
116	4653	40.11	KDOV-ETAR
114	833	7.31	LERT-OAKN
112	1166	10.41	LERT-OAIX
104	1075	10.34	KCHS-LERT
93	5151	55.39	KSUU-PHIK
90	2470	27.44	KDOV-ETAD
84	1087	12.94	ORAA-LERT
79	4428	56.05	PHIK-KSUU
70	2424	34.63	KWRI-ETAR
64	2831	44.23	PHIK-PGUA
63	677	10.75	ETAR-OAKN
59	970	16.44	ETAR-OAIX
54	446	8.26	LERT-OKBK

Figure 42 Greater Than 50 C-5 Flights Over Water

Count of Flights	Total Passengers	Average Passenger	Name
90	1514	16.82	KDOV-KSUU
83	1242	14.96	KSUU-KCHS
74	1099	14.85	KCHS-KDOV
69	677	9.81	KDOV-KCHS
58	411	7.09	KGRK-KDOV
51	1841	36.10	KWRI-KDOV
50	635	12.70	OAKN-ORAA

Figure 43. C-5 Flights with Passengers Over Water

C-17

The C-17 flew 117,672 missions since October of 2009 until March, 2013. 45% of the flights the C-17 carried passengers (Figure 44). 25% of the C-17 flights carried passenger loads that ranged from 1 to 20, 7% of flights carried 21 to 40 passengers, 2% of passengers between 60 to 100, and 6% of flights carried more than 100 passengers.

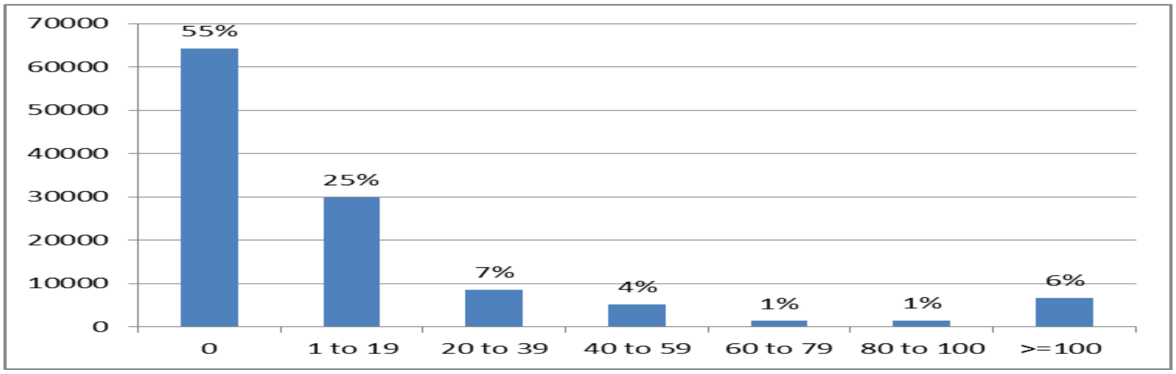


Figure 44. C-17 with Passengers

Of the flights that carried passengers, 56% of the time the flight traversed at least 50 miles from the shore, where 44% of the flights did not cross more than 50 miles per FAA EOW regulations (Figure 45). Based on the data provided, the following results adhere to the FAA: 0 rafts are needed approximately on 89% of all flights because there were no passengers or the aircraft did not fly over the water. Two to 3 rafts are needed on the remaining 11% of flights (Figure 46).

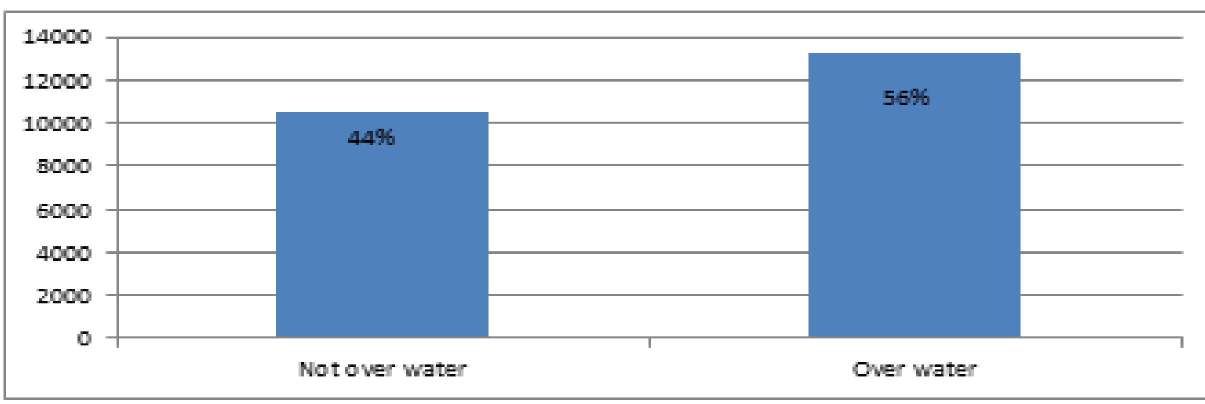


Figure 45. C-17 Flights with Passengers Flown over Water

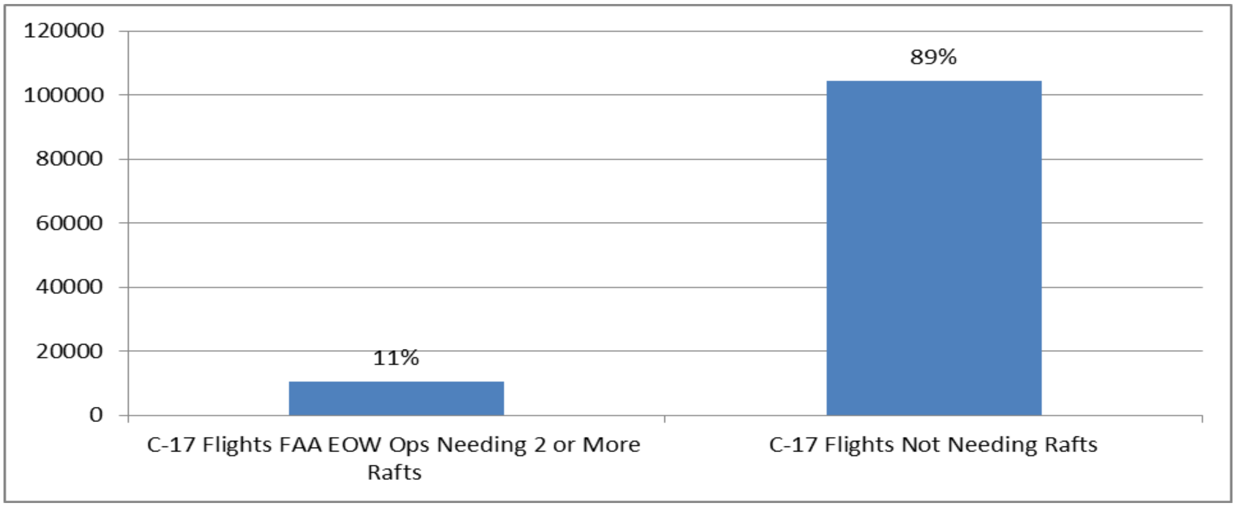


Figure 46. C-17 Total Flights Needing Life Rafts

The Google Earth maps depict C-17 flights with passengers from October 2009 until March of 2013 (Appendix D, C-17). The white lines indicate flights that did not pass over bodies of water greater than 50 miles.

Five hundred and seven C-17 departures with passengers, over water, flew in-between Germany and Bagram airfields (Figure 47). As depicted on this chart, most of the flights occurred in the current area of operations in South West Asia. However, the number dwindles in comparison to the training flights that occur at the main bases for the C-17. For example, there were 3,495 flights that took off and landed at Travis Air Force Base or 3,304 flights out of Charleston during the same time period. It is impossible to know if these aircraft flew greater than 50 miles from land, but is assumed that the majority was low levels, air-drops, or local landing sorties.

Number of Flights	Total Passengers	Average Passenger	Name
507	10105	20	ETAR-OAIX
467	7906	17	OAIX-ETAR
418	6800	16	OTBH-ETAR
377	10110	27	KCHS-ETAR
350	6509	19	ETAR-KDOV
312	5708	18	ETAR-OAKN
288	5923	21	ETAR-KWRI
274	8065	29	ETAR-OTBH
230	5323	23	KWRI-ETAR
227	4937	22	ETAR-KCHS
223	5345	24	ETAR-CYQX
211	2956	14	KDOV-ETAR
206	2026	10	ETAR-KADW
188	2433	13	KDOV-ETAD
186	3137	17	KADW-ETAR
184	6843	37	KPOB-ETAR
176	3223	18	CYQX-ETAR
172	8	0	ETAR-OAZI
165	4	0	PHIK-PGUA
165	1332	8	ETAR-OKAS
161	66	0	UAFM-ETAR
150	3615	24	ETAR-KBGR
139	5	0	PGUA-PHIK
129	2961	23	KBGR-ETAR
113	2271	20	ETAD-KCHS
109	4360	40	ETAR-KPOB
102	1699	17	ETAD-CYQX

Figure 47 C-17 Flights with Passengers Over Water

The large percentage of flights flown with passengers and not over water occurred between the main operating bases for the C-17 such as Charleston and McGuire Air Force Base (Figure 48).

Number of Flights Not Over Water	Total Passengers	Average Passenger	Name
226	1379	6.10	KCHS-KADW
218	2157	9.89	KCHS-KDOV
209	2342	11.21	KADW-KJAN
186	2336	12.56	KWRI-KTCM
173	2541	14.69	KTCM-KDOV
160	3158	19.74	CYQX-KCHS
150	2359	15.73	KSUU-KADW
135	769	5.70	KADW-KCHS
133	1006	7.56	KSUU-KRIV
124	15	0.12	UAFM-ETAD
115	1703	14.81	KDOV-KCHS
112	1485	13.26	KBLV-KTCM
111	1069	9.63	KRIV-KSUU
104	552	5.31	KDOV-KADW

Figure 48. C-17 Flights with Passengers Not Over Water

C-130

The C-130 flew 182,242 missions since October of 2009 until March 2013 and had the least amount over water. This is not surprising because it is a tactical airlift aircraft versus the other strategic airlift aircraft in this study. Basically, the C-130 will fly shorter distances and is used primarily for intra-theater moves. 67% of the flights did not carry passengers (Figure 49). Thus, 17% of the flights carried passenger loads that ranged from 1 to 20, 8% of flights carried 21 to 40 passengers, and 6% of flights carried more than 41 passengers, and 2% had 61 or more passengers.

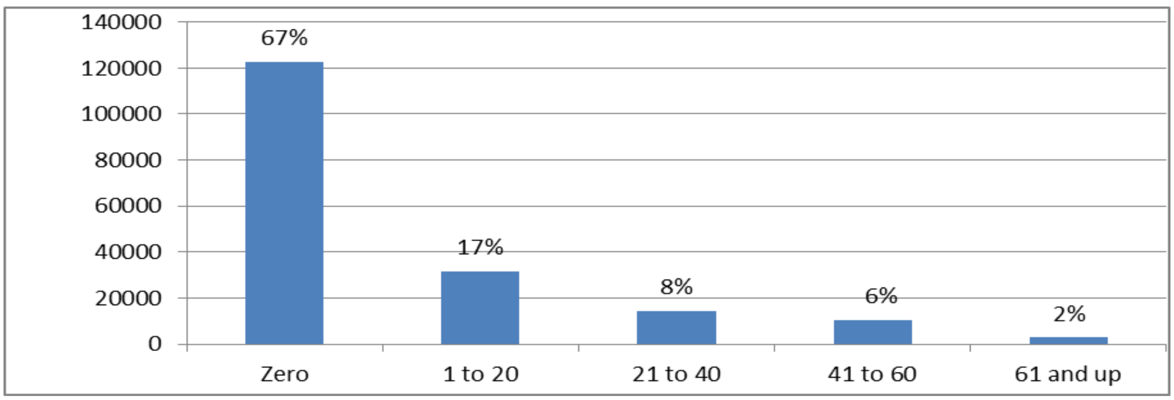


Figure 49. C-130 Number of Passengers on Flights

As stated previously, flying passengers does not necessitate carrying life rafts; however, it does when they are flown over water (Figure 50). Of the flights that carried passengers, 4% of the time the flight traversed at least 50 miles from the shore, where 96% of the flights did not cross more than 50 miles per FAA EOW regulations. In total 1% of all flights carried passengers and traversed over the water (Figure 51).

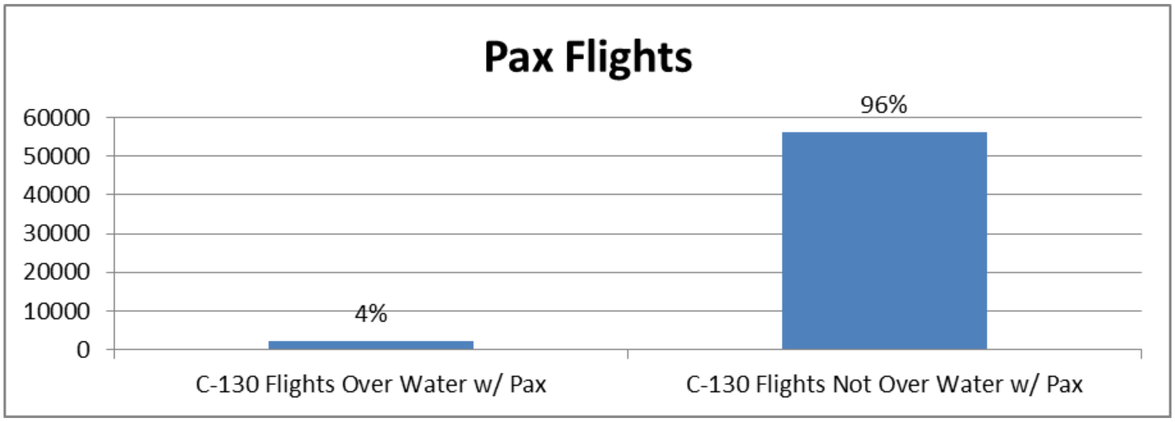


Figure 50. C-130 Flights with Passengers Flown over Water

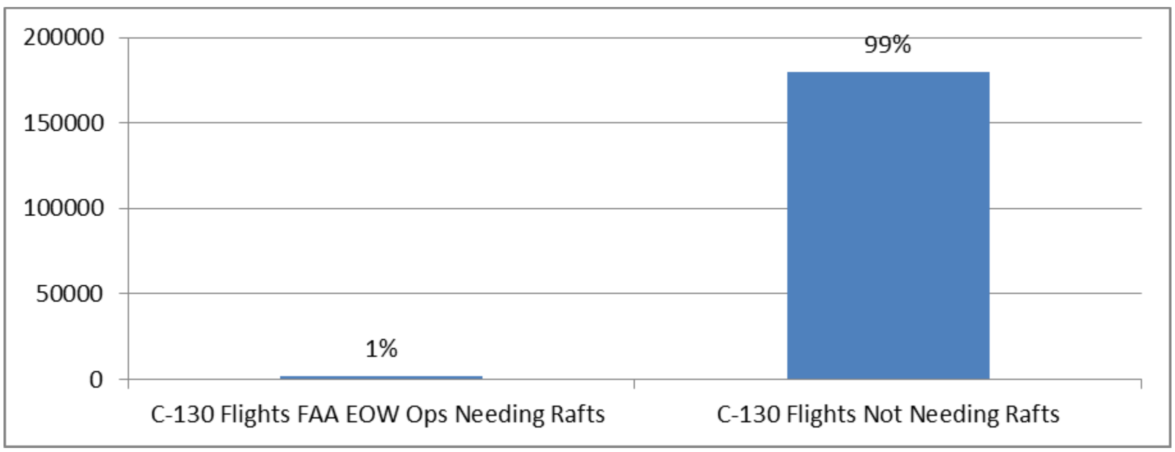


Figure 51. C-130 Number of Flights Needing Life Rafts

Life raft requirements by the FAA also stipulate that if the primary raft were to be unusable, a back-up raft is available. Due to this stipulation, the following results adhere to the FAA: 0 rafts are needed on 99% of all flights; 2 to 4 rafts would be needed on the remaining flights.

The C-130 main bases comprise the most flights that occur in the C-130. For example, 14,087 flights originated out of Little Rock AFB and 12,347 of those flights returned to that

station. The other main hubs for C-130s show a similar flight number and comprising close to 40% of all C-130 flights.

C-130 flights that are over water with passengers are few and far between but occurred most frequently between the flights of Saint John's Airfield and Glasgow Prestwick Airfield (Figure 52).

Count of Flights	Departure	Arrival	Total Passengers	Average Passenger
50	CYYT	EGPK	866	17.3
81	MUGM	TJSJ	666	8.2
85	RJTY	RODN	584	6.9
94	RODN	RJTY	995	10.6
103	MUGM	MKJP	2919	28.3
106	MKJP	MUGM	2999	28.3

Figure 52. Greatest Number of C-130 Flights with Passengers Over Water

The Google Earth maps depict C-130 flights with passengers from October 2009 until March of 2013 (Appendix D, C-130). The white lines indicate flights that did not pass over bodies of water greater than 50 miles.

KC-10

The KC-10 flew 12,158 missions since October of 2009 until March, 2013, where 76% of the KC-10 flights carried passengers (Figure 53). KC-10 flights carried passenger loads that ranged from 1 to 20, 5% of flights carried more than 21 passengers. Only 17% of the flights needed 2 or more life rafts based on FAA regulations and 83% of the time they did not need life rafts (Figure54). Of the sorties that did carry passengers, 70% of them flew over water (Figure 55).

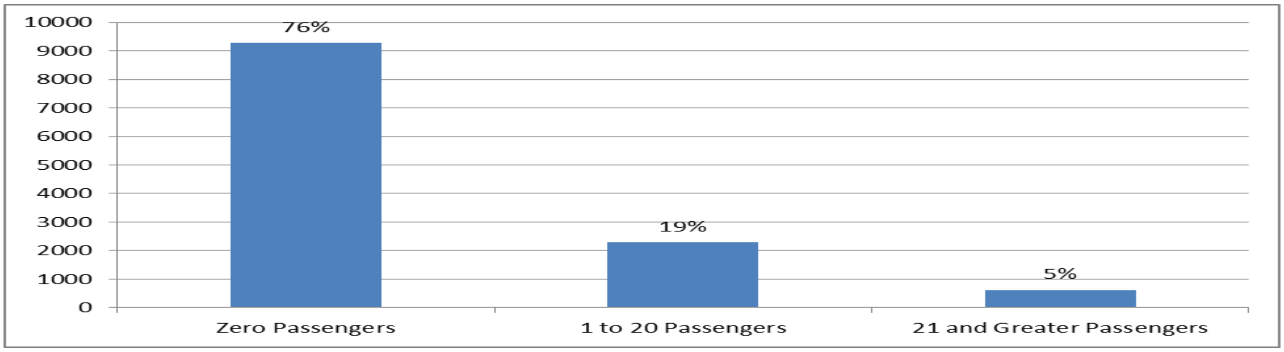


Figure 53. KC-10 Range of Passengers

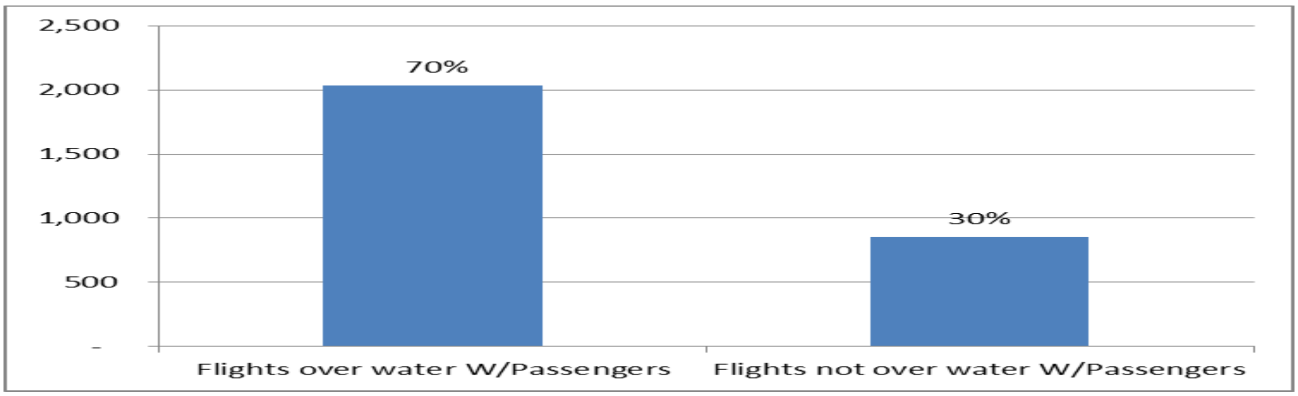


Figure 54. KC-10 Flights w/Passengers

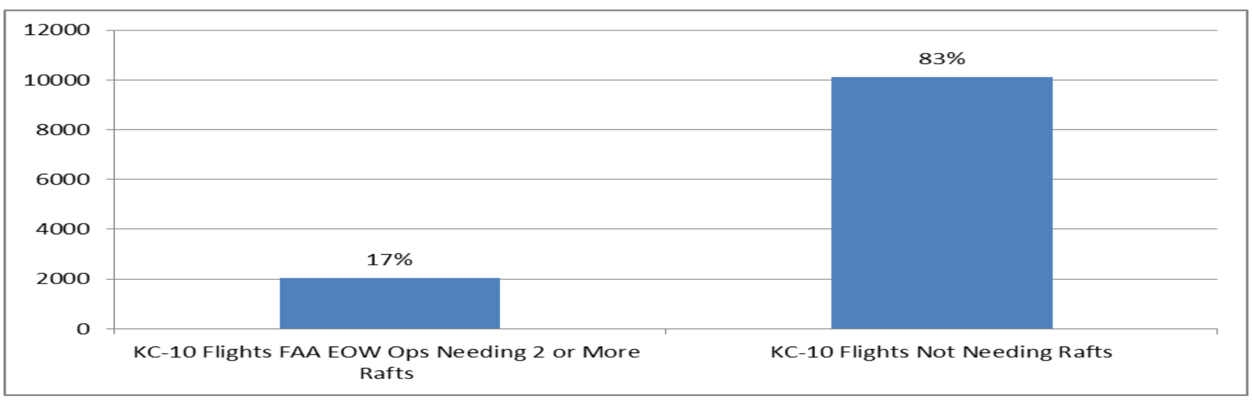


Figure 55. KC-10 Flights Needing Rafts

The majority of flights that carried passengers over water are from Travis Air Force Base to Hickam Air Force base. The other flights are mainly over the Pacific, and 55 from McGuire

Air Force Base to Moron Spain (Figure 56). The majority of all flights are the local training sorties. For example, there were 426 sorties that departed Travis Air Force Base and returned while McGuire Air Force Base had 600 of these flights.

Count of Flights	Departure	Arrival	Total Passengers	Average Passenger
168	KSUU	PHIK	3419	20.35119048
139	PHIK	KSUU	2844	20.46043165
69	PHIK	PGUA	596	8.637681159
55	LEMO	KWRI	515	9.363636364
54	PGUA	PHIK	580	10.74074074

Figure 56. KC-10 Greatest Number of Flights Over Water w/Passengers

The Google Earth maps depict KC-10 flights with passengers from October 2009 until March of 2013 (Appendix D, KC-10). The white lines indicate flights that did not pass over bodies of water greater than 50 miles.

KC-135

The KC-135 flew 63,120 missions since October of 2009 until March, 2013 where 89% of the time the aircraft did carry passengers (Figure 57). KC-135 flights carried passenger loads that ranged from 1 to 10 7% of the time, and 4% of flights carried more than 11 passengers.

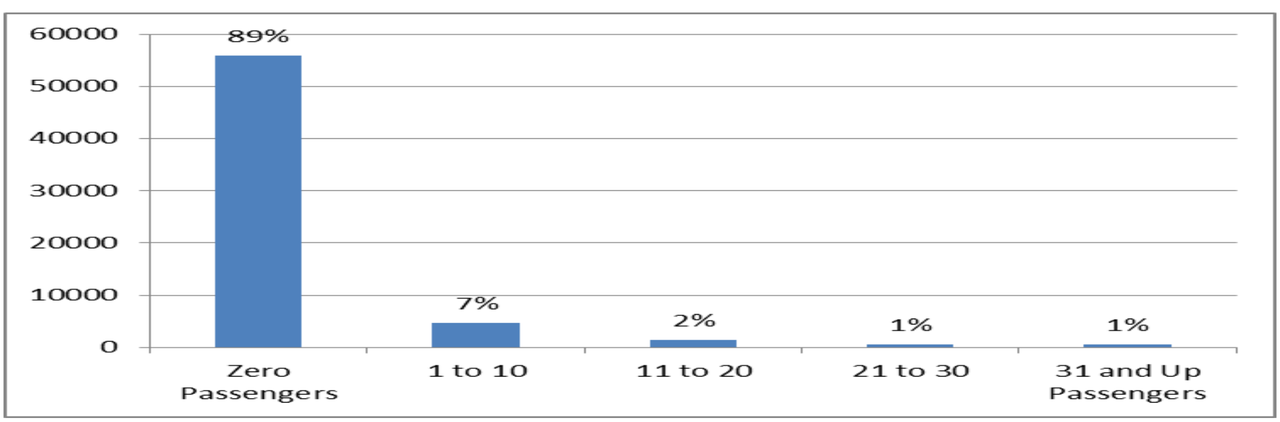


Figure 57. KC-135 Flights

Only 6.8% of the time the aircraft needed 2 or more life rafts based on FA regulations and 93% of the time they did not need life rafts (Figure58). Of the flights that did carry passengers, 59% of them did traverse over water (Figure 59). The most frequent flights over-water, with passengers, occurred between Travis Air Force Base and Hickam Air Force Base with a total of 201 flights, transporting a total of 2104 passengers or about 10 per flight (Figure 60). Training sorties were once again the highest number of sorties. Mildenhall, MacDill, and Fairchild Air Force Bases had at least 962 training sorties during this period.

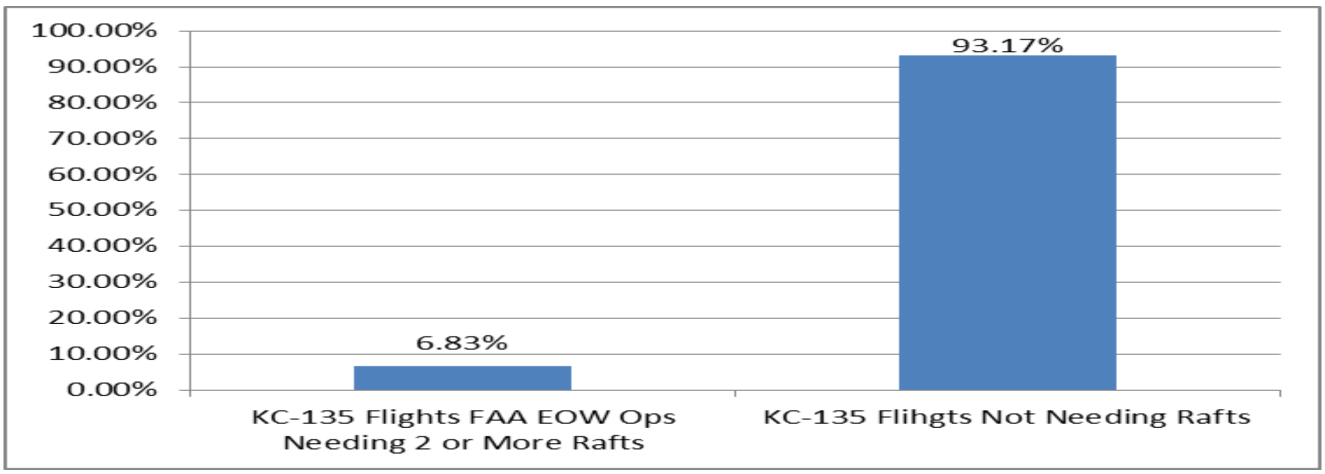


Figure 58. Number of KC-135 Flights Needing Life Rafts

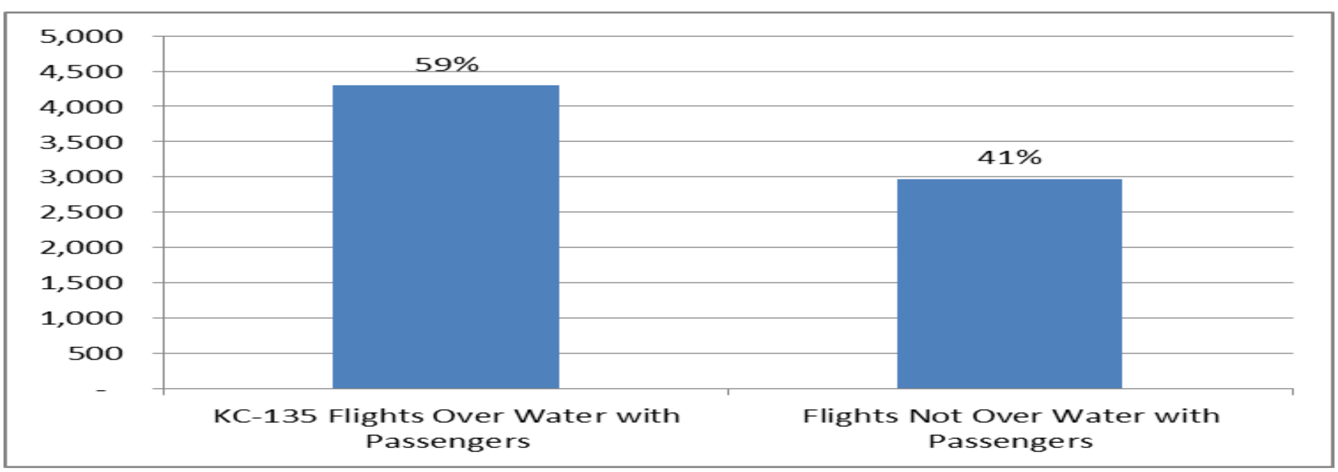


Figure 59. KC-135 Flights With Passengers

Count of Flights	Departure	Arrival	Total Passengers	Average Passenger
201	KSUU	PHIK	2104	10.46766169
184	ETAR	OAIX	892	4.847826087
175	PHIK	PGUA	2318	13.24571429
164	PHIK	KSUU	1630	9.93902439
152	OAIX	ETAR	350	2.302631579
150	PGUA	PHIK	2241	14.94
136	PHIK	RODN	1219	8.963235294
120	EGUN	KIAB	1546	12.88333333

Figure 60. KC-135 Most Frequent Flights Over-Water with Passengers

The Google Earth maps depict KC-135 flights with passengers from October 2009 until March of 2013 (Appendix D, KC-135). The white lines indicate flights that did not pass over bodies of water greater than 50 miles.

In Summary, the C-130 flies the least amount of sorties over water with passengers followed by the KC-135, C-17, KC-10, and the C-5 (Figure 61).

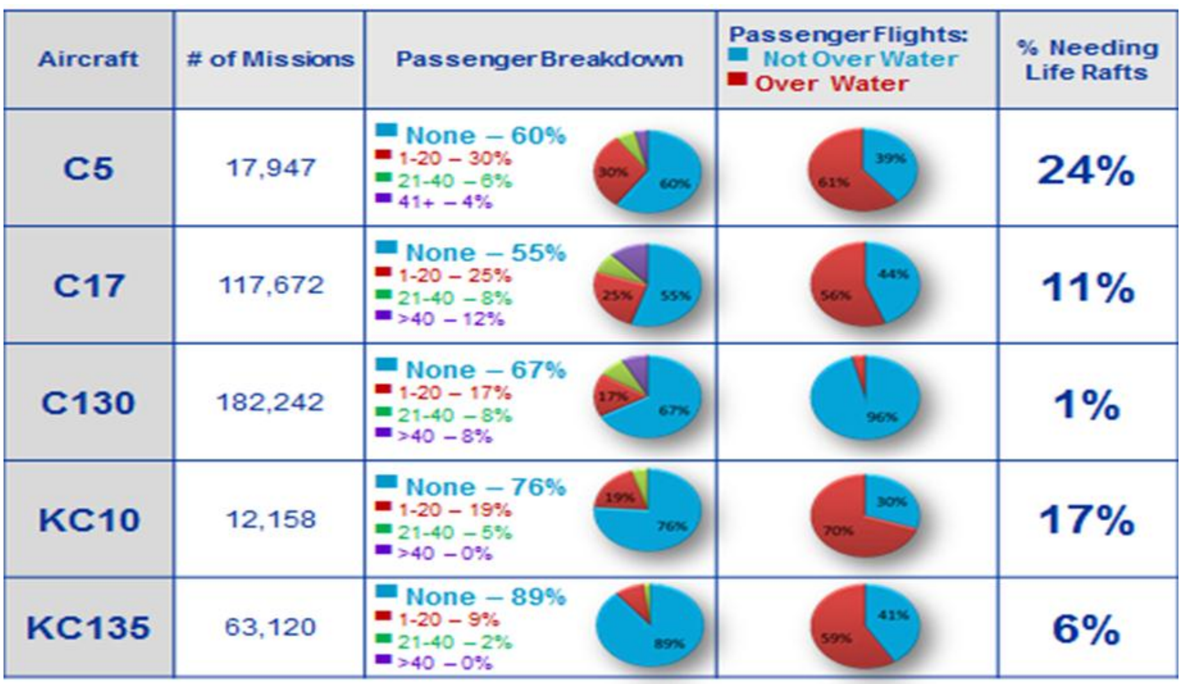


Figure 61. Analysis Summary

Life Raft Removal Savings

There are multiple costs to life rafts such as the procurement, training of personnel to maintain and utilize the equipment, and the ferry cost of life rafts. Even though the man-power and procurement costs are extremely large, this section will only discuss the past cost and future cost of ferrying this equipment on board the C-5, C-17, C-130, KC-10, and KC-135.

There are three main items needed to calculate the cost of ferrying the large life raft: 1) The weight of the life rafts per aircraft 2) Cost of weight (COW) per aircraft as discussed earlier, 3) Flight hours. The weight of the life rafts was pulled from the multiple technical orders on the airframes and included the life raft, the CO2 container, age kit, survival kit, and container weight. The cost of weight was provided by Cyintech during the 2008 study.

And lastly, the flight hours are pulled from LIMS-EV a database that contains the aircraft still in service. Unfortunately, the aircraft that are no longer in service do not show up on LIMS-EV. Due to this constraint, an assumption is made that the retired aircraft to have flown at least the average number of hours as the aircraft that exist in LIMS-EV.

The total historic cost is also based on a set gas price. Jet fuel was a lot cheaper in the late 1950s when some of the C-130s and KC-135s were in the service. However, it is assumed in this study that the price has not change. Because of these points, a fuel cost of $3.73 was used which coincides with the fuel cost that is currently the DLA provided rate.

The total cost of having large life rafts on board these aircraft totals to approximately $368 million. In Fiscal Year 2013, the cost of ferrying these life rafts is predicted to cost $7.7 million (Figure 61).

	PREDICTED HISTORIC COST OF LIFE RAFTS, AND ESTIMATED COST FOR 2013				
	C-5	C-17	C-130	KC-10	KC-135
Total Weight Life Rafts Weight, CO2s, Ages, Containers	844	684	780	380	585
COW	5.67%	4.40%	3.00%	4.47%	4.97%
FY13 Hrs	31994	175124	140039	39405	113262
Gallons Used in FY13	226,489	779,664	484,750	99,014	487,136
Cost for FY13 at $3.73	$844,804	$2,908,149	$1,808,119	$369,321	$1,817,015
Total FY13 Cost	$7,747,409.00				
Number of Aircraft (LIMS-EV)	74	217	362	59	414
Average Hours (LIMS-EV)	20,348	10,831	10,126	27,106	21,316
Total Hours (LIMS-EV)	1,505,735	2350377.4	3,665,490	1,599,244	8,824,914
Total Historic Gallons Used (LIMS-EV)	10,659,269	10,464,047	12,688,233	4,018,456	37,955,614
Total Cost (LIMS-EV)	$39,759,072	$ 39,030,896.00	$ 47,327,109.00	$14,988,840	$141,574,439
Total Cost (LIMS-EV)	$282,680,355				
Number of Aircraft	79	223	993	59	414
Total Hours	1,607,474	2,415,365	10,054,782	1,599,244	8,824,914
Total Historic Gallons Used	11,379,490	10,753,376	34,805,015	4,018,456	37,955,614
Total Historic Cost	$42,445,496	$40,110,091	$129,822,704	$14,988,840	$141,574,439
Total Cost	$368,941,569				

Figure 62. Historic Cost of Life Rafts and Predicted 2013 Cost. (LIMS-EV, FY 13 POM, FEO, 2013)

Delphi Results

Round One

The first round of the Delphi Study introduced the members to the purpose of this study, the significance of their opinions, the background to the study, the process of the Delphi Study, background questions, one Likert scale question, and seven open-ended questions (Appendix A). The purpose of the Delphi Study conveyed to the panel that this was a qualitative and quantitative research tool that would be free from group-think, group collaboration, and other influences. In addition, the expectation was set that this study may take three-four rounds dependent on the answers and group consensus.

The background to the initial survey discussed the rules for carrying large life rafts that are based upon the FAA regulations. The background also posed the question that as our aircraft,

flight systems, and flight structure change so do ditching efforts and the use of life rafts. The question ultimately asked at what point in time the cost of life rafts exceeds the utility that they provide. In order to determine this answer, the Delphi Study asked basic open-ended questions that would further drive the discussion of the panel.

In this study, the amount of questions and data provided was set at an optimal length to promote participation. The length of the study can lead to participant dropout, curtailed answers and loss of interest as noted earlier by Linstone and Turoff (2002). It was important to be precise with the data provided. This ensures that the panel is not influenced through facilitator bias. Background questions were initially asked to ascertain their qualification. There were five questions to gather their current job title, time in position and core Air Force Specialty Code (AFSC). There was also one question that asked their experiences with large life rafts.

The eight open ended questions provided direction for round two of the Delphi study. The eight questions were answered by the panel and categorized into similar concepts. Each of the eight questions had the number of categories associated with it respectively: 1) six, 2) three, 3) two, 4) three, 5) six, 6) seven, 7) seven, and 8) five. When all categories were combined there were a total of 18 different categories.

17 members participated in the first round of the Delphi Study. The expert panel was first asked to evaluate the following statement using a Likert scale: On a scale from 1 to 5 (1-strongly disagree, 3-neither agree/disagree, 5-strongly agree), please assess the statement, “Large life-rafts (20-man or greater) are essential to the safety of our Airmen flying the C-5, C-17, C-130, KC-10 and KC-135.” The panel was also asked to elaborate on their response. The average score from

the panel was 3.94 (Figure 62).

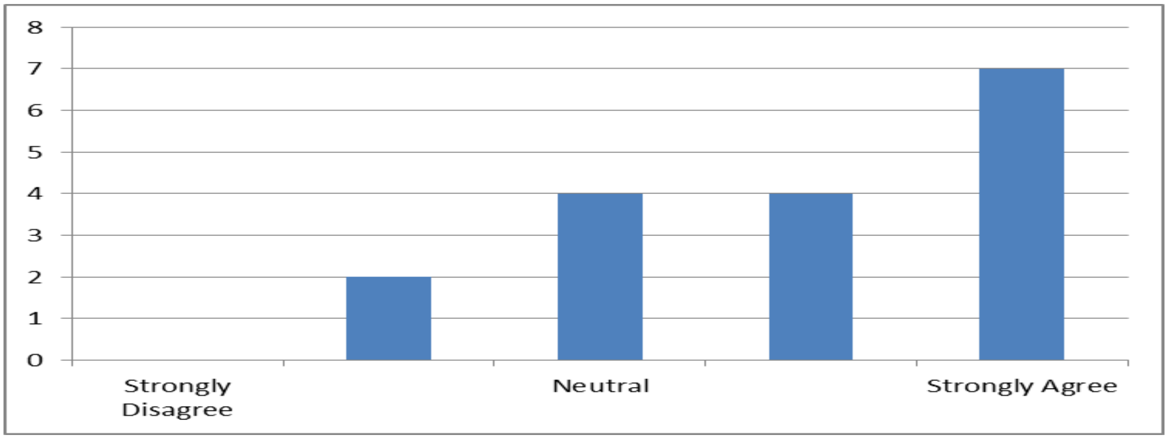


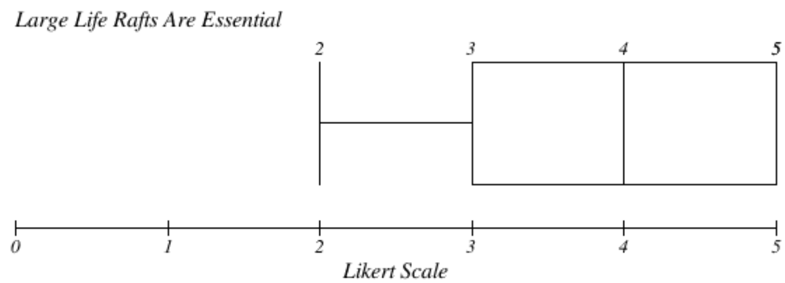
Figure 63. Round 1 Question 1. Large Life Rafts are essential to the safety of our Airmen flying the C-5, C-17, C-130, KC-10, and KC-135

There were two members who disagreed with the statement, four members who were neutral or agreed, and seven members that strongly agreed. The elaboration on the responses ranged from short to multiple paragraph answers. The answers were categorized into six different subjects (Figure 63).

Unacceptable Loss In The Event of Failure In The Future, Essential Safety Equipment	13
FAA Requirements	9
When Was the Last Ditching? Very Low Utilization Rate of Large Life Rafts	9
Ethical Responsibility	7
Morale of Airmen and Passengers	6
Life Rafts Will be Unusable in Ditching Event	2

Figure 64. Round 1 Question 1 Grouped Responses

The box plot and statistical data from the question reveal an interquartile region of two with a median and mean of approximately four showing agreement that life rafts are essential for the safety of our Airmen (Figure 64).



Mean	3.941176
Std Dev	1.088037
Min	2
Q1	3
Median	4
Q3	5
IQR	2

Figure 65. Round 1 Question 1 Box Plot and Statistical Data

The second open-ended question asked the panel members to discuss the driving factors for putting large life rafts on the aircraft. The responses were categorized into 3 different subjects: 1) Crew & passenger safety and sense of safety with a total of 16 comments, 2) FAA regulations with a value of 7 comments, 3) Aircraft capability and reliability were lower; ditching was more frequent, especially due to the conflicts at the time with a value of 5 comments.

In the first category, the safety and sense of safety provide to Airmen and passengers by life rafts were the most important reasons. Five members on the panel did comment that the reliability of the aircraft and the missions that were flown necessitated life rafts because of the high chance of utilization.

The third question attempted to better understand if the dynamic factors for life rafts still remain today. There were a total of 14 panel members who answered “no," stating that the driving factors for large life rafts have not changed. Three members answered yes, noting that the aircraft reliability and airspace regulation has changed since the initial regulations. Although 14 of the members stated that the factors had not changed, 8 of their responses noted that aircraft reliability, and the current mission has changed.

The panel concluded three main concerns addressing the removal of life rafts. First, life rafts are necessary equipment. When a ditching event occurs, crew or passengers will die if they do not have it. Second, Air Force policy to remove life rafts is unacceptable even if one person died from exposure. Third, the panel discussed that the life rafts provide a sense of safety and improved morale. If life rafts were removed to save money, it would have grave consequences to the mindset of our force.

The fifth question asked the panel to describe the benefits of removing the large life rafts. There were six categories that emerged from this discussion: 1) Water Survival Training/TDY cost reduction, 2) Fuel Savings, 3) AFE/MX labor savings, 4) Procurement savings, 5) Increased space and weight capacity of the aircraft, 6) Aircraft cost savings due to design changes.

The next question asked the panel to evaluate their concerns against their stated benefits and explain which one is more important and why. Thirteen of the panel members noted that their concerns outweighed the benefits, three stated the reverse. The three members suggested that the savings were not significant enough and there are bigger savings within the Air Force. Fourteen of the panel members stated that the removal of life rafts is an unacceptable policy for the Air Force. Lastly, three members noted that the savings did exceed the safety features of the large life rafts.

The panel members were asked to discuss recent removal of parachutes from the aircraft, and if that could be comparable to the removal of large life rafts. Four of the members stated that the removal was similar and 11 voiced that it was not. The main difference, that the panel mentioned, was that life rafts are used for passengers as well as aircrew members where the parachutes are only for aircrew. Six of the panel members also discussed that jumping out of the aircraft was riskier than ditching the aircraft and therefore, the option of ditching is preferable.

The panel could include any additional comments that they were unable to do previously. The responses gathered from this section were very helpful because it provided the room for open dialogue to steer the discussion. The panel discussed in detail how the Air Force could instantly save much more money by cutting flying hours or improve our combat efficiency. If life rafts were temporarily removed, the manpower is not sufficient and the cost savings would quickly diminish, thus necessitating preserving life rafts on all missions.

The panel also discussed how the civilian airlines have looked at removing life rafts from their aircraft. This discussion never ended with the removal of life rafts, mainly due to the accepted risk by the airline and the public appearance. The removal of life rafts could be shown to be a good decision based upon the money saved and given the extremely rare utility rate. Nevertheless, the decision has always been to keep the life rafts primarily due to ethical and public concerns.

The panel also thought that it would be worthwhile to examine the possibility of removing life rafts or reducing the number of them on future aircraft. Some of the panel members who believe large life rafts are not necessary stated that the Air Force was more risk averse than ever before. This is ultimately hurting our mission capability while providing little benefit.

The last common theme that was addressed was the value of life, and how the Air Force makes decisions on safety equipment based on the chance of saving aircrew or passengers.

The first round of the Delphi study was very successful. The participation rate was 100%, and the panel responded to every question with thorough answers. The panel is made up of experts within their career field and has an extensive knowledge on the subject. The answers from round one provided the means to develop the second round of the Delphi study.

Round Two

Round two was made up of the answers from the first round. It was comprised of one question using the Likert scale, two questions using the Ordinal Scale, and two questions asking the panel their opinion that resulted in a numerical value with an unlimited range (Appendix B).

The first question asked about the recent ditching of flight 1549 into the Hudson River (Figure 65). The panel felt strongly that flight 1549 crash into the Hudson River did not change their mind on the carrying of life rafts (Figure 66). Although they came to a similar conclusion on the question, their explanation varied. Eight of members mentioned that it did not change their mind because they once again stated that all flights regardless of path should carry life rafts because of the effort needed to constantly remove and replace the rafts.

1. On a scale from 1 to 5 (1-strongly disagree, 3-neither agree/disagree, 5-strongly agree), please assess the statement, "The US Airline Flight 1549 that crashed into the Hudson river changed my mind on large life raft requirements to be carried over land in addition to over water."	Strongly Disagree	11
		2
	Neutral	3
		0
	Strongly Agree	0

Figure 66. Round 2 Question 1, Flight 1549 Hudson River Crash

The other experts discussed that these are the secondary benefits of having life rafts aboard all missions that we conduct. One member discussed that flexibility, often noted as the key to air power, from keeping the life rafts on at all times; it enables planners to use aircraft differently than originally planned that abets in a dynamic mission and always provides the safety to our Airmen and passengers. This question received consensus and had an interquartile range of 1 with an average score of 1.5. Three of the members stated that this incident did not need the life rafts that they used because it was a river and there were boats to assist.

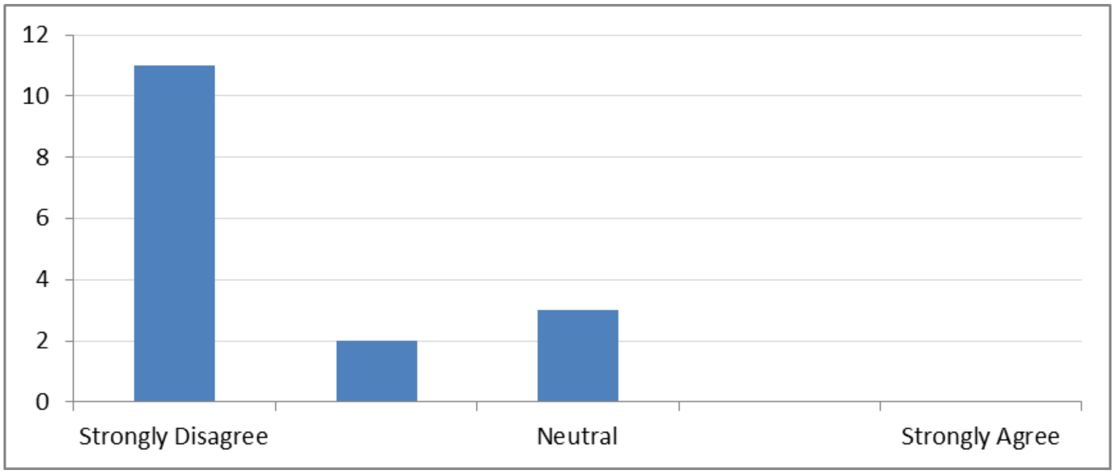


Figure 67. Round 2 Question 1, Graph Flight 1549 Hudson River Crash

Since water incidents are very uncommon and the military mission constantly changes, the second question asked the panel when they believe the subsequent water incident will occur for the airframes in the study. This question is important to the study because if there is to be a cost-benefit analysis, it provides a timeframe from which the panel believes may be the next event when the life rafts could be used. The members' answers ranged from 7 years to 35 years. The group average was 16.7 (Figure 67).

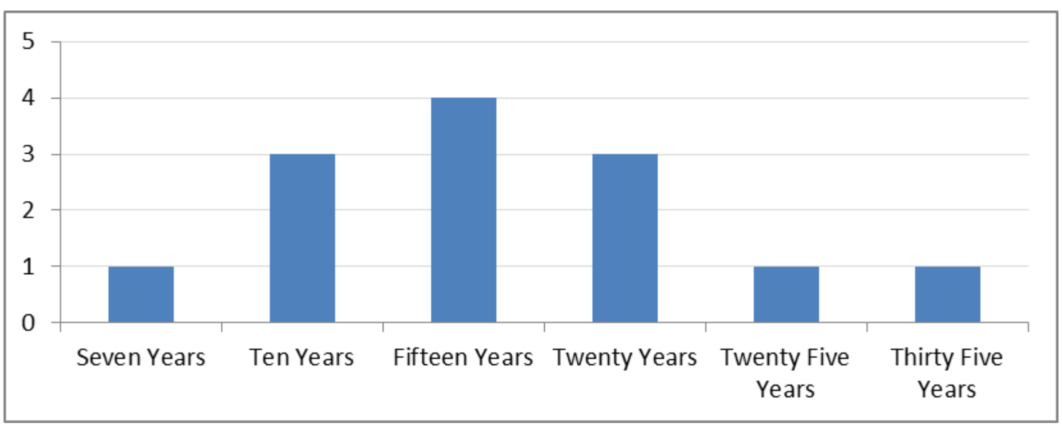


Figure 68. Predicted Number of Years Until Next Incident

The number of years until the next incident is difficult to truly figure out but it does provide information regarding the expected cost of life raft employment. The panel was also asked to provide a dollar value for the chance to save one life (Figure 68). The relative spread of answers indicates an average value of $24M (Figure 69)

Air Force Safety has a very challenging job. They must make decisions to cut or fund safety programs based on many factors but ultimately trying to save as many lives as possible within their budget. If you were put into this position, at what point would you think it is a wise decision to reevaluate large-life rafts on our large mobility aircraft? How much would you pay for the *chance* to save one life?

Loss of one life										
.25M	.5M	.75M	1M	1.5M	2M	5M	10M	50M	100M	>100M

Figure 69. Associated cost for the chance to save a life

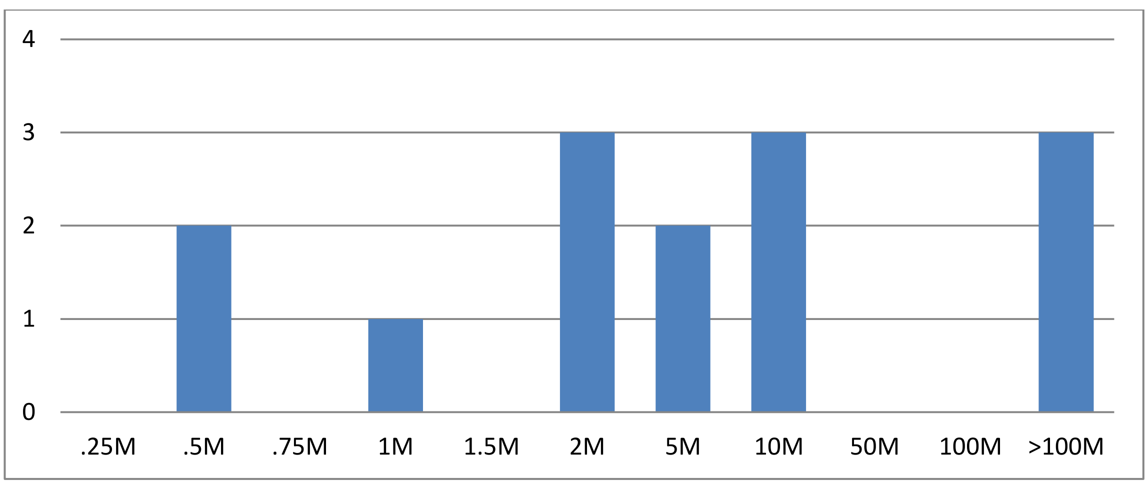


Figure 70. $M for the Chance to Save One Life

The second set of questions asked the panel to rank order seven different aspects that were primary concerns from round one (Figure 70, 71, 72). The sorting of questions was further

refined by looking at the members top two answers as well as their bottom two answers to identify priorities.

1. Large life raft removal could only be implemented on missions without passengers or flights over land. Therefore, large life rafts would have to be continually removed and replaced creating a major problem for our workforce and mission.
2. As aircraft become more reliable, we should consider removing large life rafts from our aircraft flying over water in non-combat zones.
3. Our large mobility aircraft face threats different from commercial airlines. These threats necessitate life rafts on our aircraft.
4. A cost benefit analysis of removing life rafts could show that they are a poor investment for achieving safety.
5. If the FAA's policy did not require large-life rafts, the Air Force should consider removing the large life rafts.
6. A water landing will occur in the next ten years and large life rafts will save lives
7. If large life rafts were removed it would negatively impact our organization's moral. (Airmen would feel that the Air Force is trying to save a buck while putting them and their mission more at risk).

Figure 71. List of Policy Statements for Ordinal Ranking by Panel

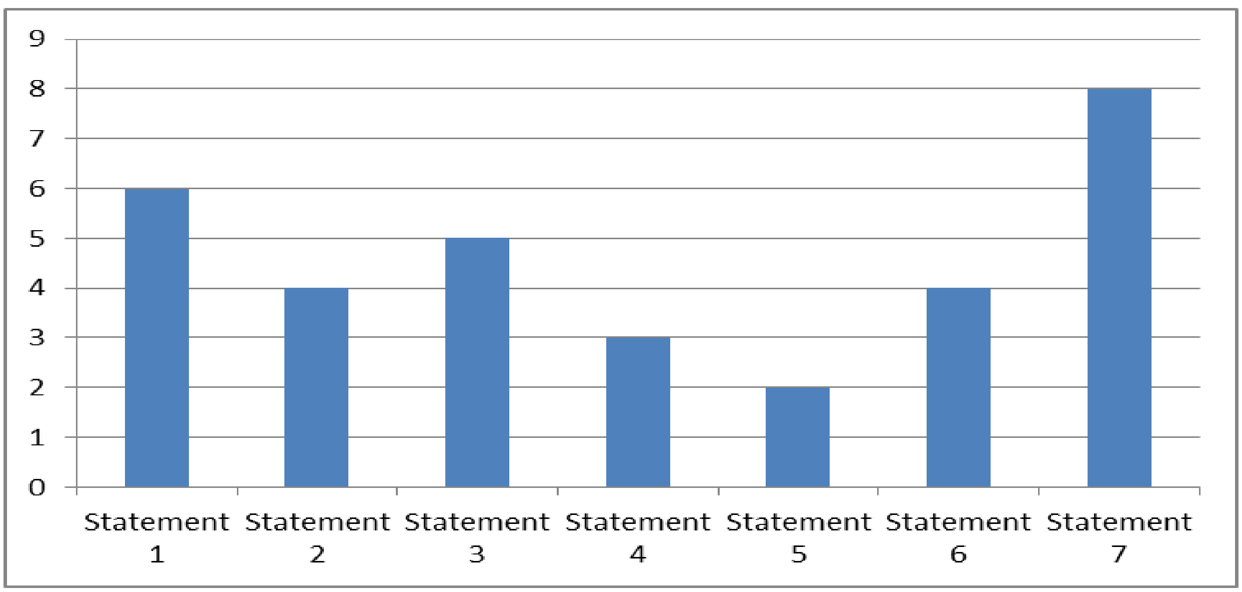


Figure 72. Top 2 Statements (Answer as 1 or 2)

Based on the average value calculated on each question, seven and one had the greatest importance to the panel. This validates the previous information provided from the panel, that discussed the labor and cost associated with removing life rafts based on an over-water flight. It also validates that the morale and image of removing these life rafts to the crew, and passenger is a significant reason for keeping life rafts aboard the aircraft. This further validates the previous point because the panel weighted it in the less important range signifying that as the reliability of aircraft improves it should not be the main determinant for carrying life rafts.

Question 5 showed few important-votes and the most least-important-votes, indicating that if the FAA changed regulations on carrying life rafts the Air Force would most likely not follow suit (Figure 72). One panel member stated that the Air Force's mission was unique and should not be based upon the FAA's guidance but should be a minimum standard because of the mission that we face daily. Question 3 ties into this theme, based on the panel's ranking it is the third most important. Because it indicates that the military's mission is quite different than that of the airlines due to the unique mission and threats that frequently emerge.

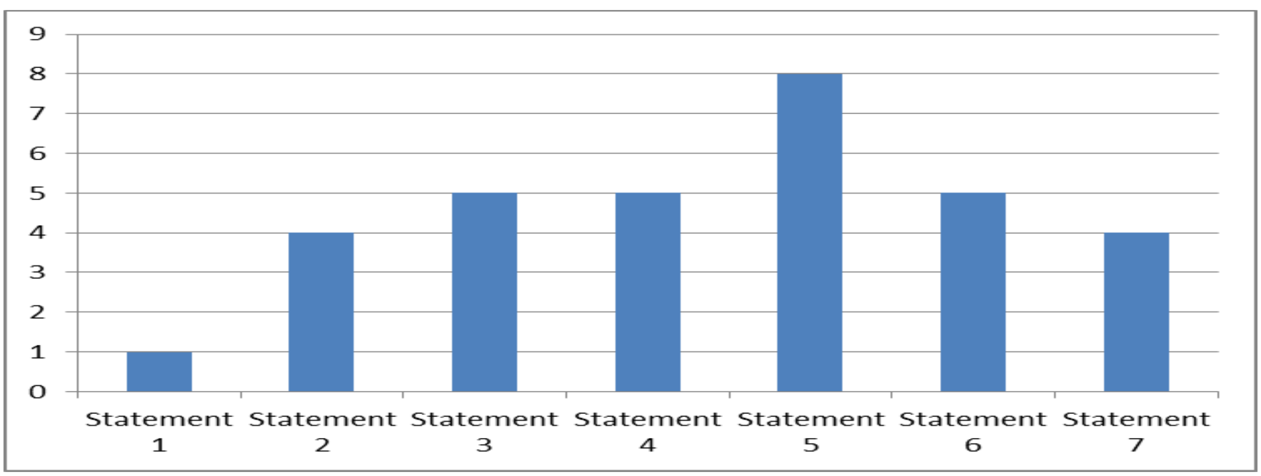


Figure 73. Least Important Statements (6 or 7)

The results of the second round illustrate similar patterns to the written information that the panel provided (Figure 73)

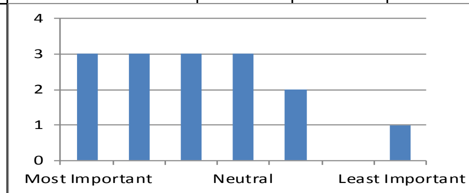
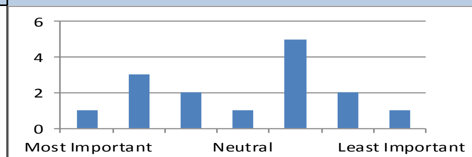
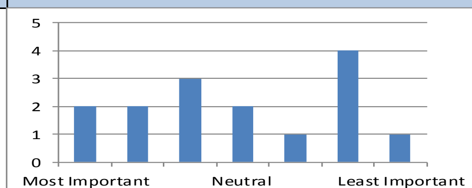
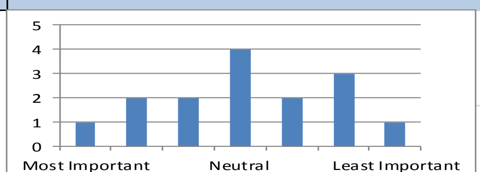
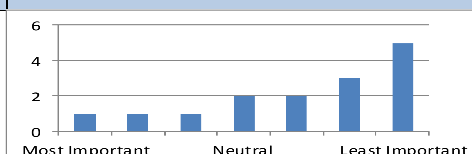
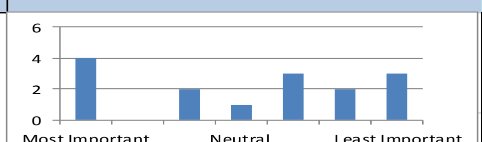
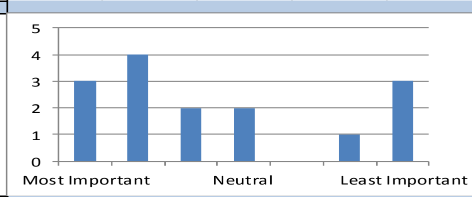
Rank Order	1=Most Important	7=Least Important	Rank
1b) Large life raft removal could only be implemented on missions without passengers or flights over land. Therefore, large life rafts would have to be continually removed and replaced creating a major problem for our workforce and mission.	Group-Average: 3.1 Group Std Dev:1.73 Group Mode:1-4		Avg: 1 Med:3 IQR: 2
2b) As aircraft become more reliable, we should consider removing large life rafts from our aircraft flying over water in non-combat zones.	Group Average:4 Group Std Dev:1.8 Group Mode:5		Avg: 4 Med:5 IQR:3
3b) Our large mobility aircraft face threats different from commercial airlines. These threats necessitate life rafts on our aircraft.	Group Average: 3.9 Group Std Dev:1.98 Group Mode:6		Avg:3 Med: 3 IQR: 4
4b) A cost benefit analysis of removing life rafts could show that they are a poor investment for achieving safety.	Group Average:4.1 Group Std Dev:1.7 Group Mode:4		Avg: 5 Med:4 IQR:3
5b) If the FAA's policy did not require large-life rafts, the Air Force should consider removing the large life rafts.	Group Average: 5.1 Group Std Dev:1.96 Group Mode:7		Avg: 7 Med:5 IQR:3
6b) A water landing will occur in the next ten years and large life rafts will save lives	Group Average: 4.1 Group Std Dev: 2.32 Group Mode: 1		Avg: 5 Med:4 IQR:5
7b) If large life rafts were removed it would negatively impact our organization's moral. (Airmen would feel that the Air Force is trying to save a buck while putting them and their mission more at risk).	Group Average: 3.4 Group Std Dev: 2.3 Group Mode:2		Avg: 2 Med:2 IQR:3

Figure 74. Delphi Results on Life Rafts

There is very little data that reveals the ditching performance for the C-5, C-17, C-130, KC-10, and KC-135. Although each flight manual offer's checklists, instructions, and many possible outcomes for a ditching event, it remains unknown on what will happen. Every ditching or water landing will also be unique based upon the weather, configuration, reason for ditching, and passenger load and impact.

Based on the previous analysis in the literature review, it was found that there has yet to be one successful ditching event on any of these platforms where life rafts were used. This begs the question to why has there not been a successful life raft employed during the 20 water incidents on the C-130 and KC-135? Many of the panel members, based on round one, felt that a ditching effort would result in catastrophe and all members aboard would die based on the impact. Other panel members felt that it would be disastrous for the image of the Air Force if a life raft could have saved a life but was removed.

The next round of questions is based on rank order and tries to examine the panel's thoughts on the future outcome of ditching effort (Figure 74). The panel members were provided four different statements and asked to rank order from one being the most likely occurrence to four being the least likely.

The panel believed, the most likely event, if a plane landed on the water, the crew and passengers would not survive the impact. The least probable event, based on the panel's answers, would be a ditching and the life rafts are destroyed or unusable.

The panel equally answered question one showing that there is a mixed feeling if life rafts save lives. There was a split vote on whether a water landing will occur.

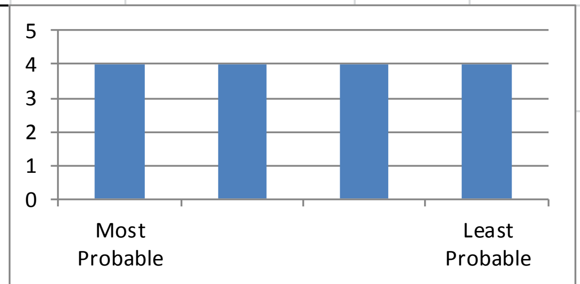
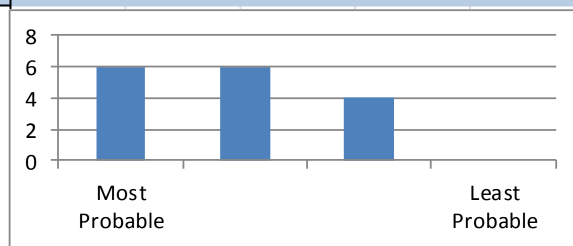
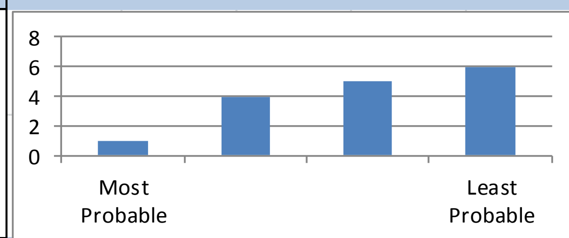
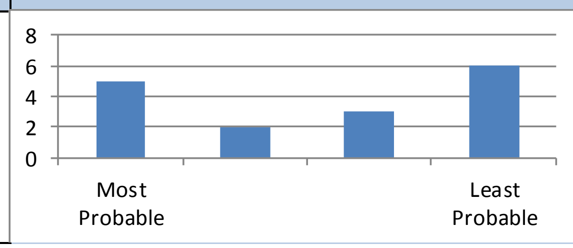
Rank Order	1=Most Probable	4=Least Probable
1a) A water landing will occur in the next X years and large life rafts will safe lives	Group-Average: 2.5 Group Std Dev: 1.15 Group Mode:Tie Rank:2	
2a) A water incident will occur in the next X years but the crew and passengers will not survive the impact	Group-Average: 1.88 Group Std Dev: .8 Group Mode: 2 Rank:1	
3a) A water landing will occur in the next X years but large life rafts will be destroyed or unusable	Group-Average: 3 Group Std Dev: .96 Group Mode: 4 Rank:4	
4a) A water landing will not occur	Group-Average: 2.63 Group Std Dev:1.3 Group Mode:1,4 Rank:3	

Figure 75. Delphi Round Two Graph Ordinal Results

In the first round, the panel mentioned the benefits of permanently removing the equipment such as fuel savings, labor, and training. However, this was not included in the second round because the information that the panel provided in round one was complete. Furthermore, in order to keep round two's questions manageable it was also deemed less critical.

Round Three

The third round of the Delphi Study can be seen in Appendix C. The participation in round three did drop from the previous round and lost one individual resulting in a 93% participation rate. The panel member could not complete the requirement due to a permanent change of station (PCS). Round three allowed the panel members to see the group response from the second round and comment on the answers. There were five total questions in round three.

The first question summarized the overall perspective of the group into one paragraph shown below. After reading the paragraph, the participants were asked if they agree or disagree and to state the reason why. The panel members were asked four open-ended questions about the results in the previous round. The results of these answers ranged from short paragraphs to full-page responses. The panel provided great insight into the reasons for the lack of consensus and for the overall rationale of maintaining large life rafts.

> *Large life rafts are critical to the safety and morale of our Airmen. Additionally, the labor, cost, and loss of flexibility from removing them are too significant. Even if aircraft reliability or aircraft performance increased, the cost-benefit analysis would not change my mind on removing large life rafts. Although regulatory, the FAA requirements are least significant in our decision process to carry life rafts because we would transport them regardless of their rules.*

Eight or 53% of the members concurred with the statement with no additions. Five or 33% of the members agreed with the statement and had minor comments. Two or 13% of the members disagreed with the statement.

The first sentence regarding the safety and morale of our Airmen received two comments. One panel member stated that life rafts were not critical for the safety or the morale of our crew

but very important to the passengers. The second comment stated that life rafts and the safety equipment that comes with them are critical to alternative emergency scenarios.

The members who disagreed with the statement answered that as technology changes so must the user. If our service is close-minded about change, it will hurt our capability because decisions lack true objectiveness. The member further stated that life rafts were not critical for the safety or to the morale of our aircrew and were similar to the removal of the parachutes. In addition, life rafts surviving the ditching event are very questionable; indicating that life rafts are not effective.

No one on the panel had comments regarding the second sentence that addressed the labor, cost and loss of flexibility if life rafts were removed. This coincides with the data from the previous rounds. Removing life rafts based upon the mission would come at a large cost in terms of labor, wear, flexibility, and storage. Another panel member presented a situation where there were six legs to a mission in which one had an overseas leg; thus, creating a logistical, manpower and tracking challenge.

Of the panel members with minor changes, two of them thought if the policies of the FAA changed than the Air Force should adapt their policy as well. And not just because it is a regulatory body; but rather, the FAA also takes into account many of the same factors that our policy makers consider. Two different panel members noted that if the FAA changed their rules that the Air Force still should not change policy. The rationale behind this is due to the unique mission that the Air Force conducts.

Question two asked the panel members about the disparity that resulted in questions one and four (Figure 74). The rationale for the disparity, based on the panel member's comments, existed partly because of the uncertain future and the location of the next ditching. Multiple

members commented that the recent shift in operations to the Pacific region created the disparity in the answers. While almost all members believed operations in the Pacific would increase the chance of ditching due to the percent of time flown over water many members did not see this shift as a probable event. Moreover, if the shift did occur to the Pacific, the intensity of that conflict would far exceed what our forces have seen in the recent decades leading to more water impact events.

The next ditching, because of the success of the Hudson crash, is another reason the panel members explained the disparity. They discussed that since the majority of crashes are occurring near airports, and population density is changing the choice to ditch in a river or lake is becoming more appealing.

Another panel member suggested that the disparity may exist because of the familiarity that each member has with certain aircraft type. Based on previous research, aircraft technical orders do not prescribe the same instructions regarding ditching. And the philosophy has changed over the last few decades regarding ditching and bailing out of aircraft. In addition, each aircraft has very different ratios of passengers and flight over water that may also present dissenting opinions based on the panel member's comment.

One member provided additional insight into this policy issue. The member stated that forecasting needs to be viewed differently than policy. Policy decisions need to be made assuming that a ditching will occur, and life rafts will save lives. Forecasting decisions even differences in some of the statements were difficult to distinguish because there were seven to rank order leading to a guess on issues in the middle of the batch.

The last important note that the members discussed is that a ditching will occur, and rafts will save someone's life, it is just matter of time.

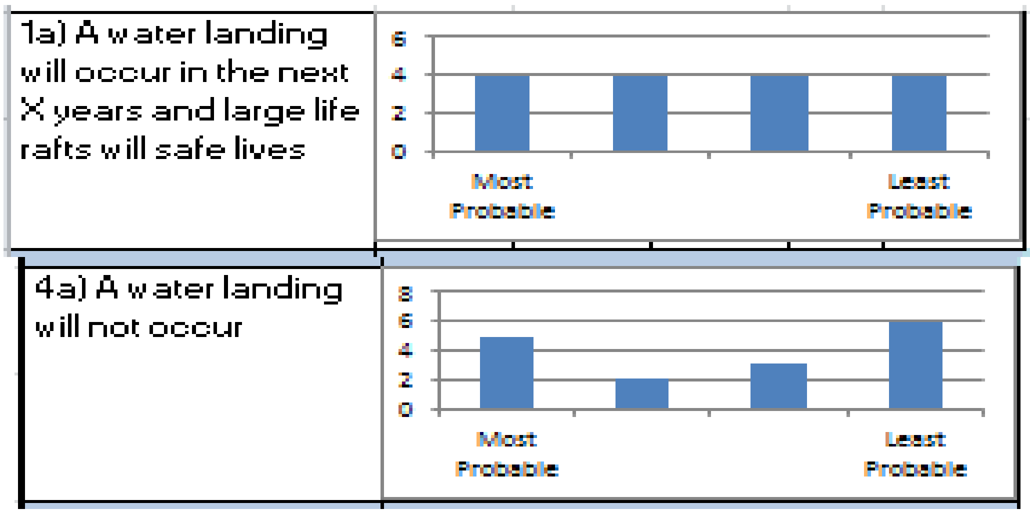


Figure 76. Disparity on Both 1a) and 4a)

The third question asked the panel members to comment about the results from the chart for statement 7b (Figure 75). Since the answers to question 7b received the most top answers shown and four of the lowest rankings it decreased its overall average significantly.

There were six main groups of responses to explain this disparity. The response that received the most comments from the panel dealt with the perception of morale. The panel members stated that they valued the safety more than the morale, and when comparing these two-safety will always win. Other panel members said they did not value the morale over safety. They also noted that if the Air Force removed them, the morale would drop due to the outcry. This would lead to public affair's nightmare. Other experts suggested that morale was not important; especially when leaders communicate the rationale and reasoning for decisions. A few of the members indicated that the difference is because morale can't be evaluated and is very subjective. Another response suggested it was likely that the disparity came from some members are pilots, and others are not. Multiple members addressed perception, and one of their statements is shown below.

> *"I view this question from a perception perspective, because in many cases, perception is reality, and in this case to error on the conservative side of perception could only serve to save lives. Conversely, if one were to make decisions in this case based on data and not perception, it would error to a less conservative approach, possibly substantiating the removal of life rafts. I suspect there is a disparity in the data because there are some that believe decisions should be made purely on data, even when the perception could result in decreases in morale. This question offers an interesting paradox, because normally I am a firm believer in factual data to support analysis, conclusions, and decision making. However, in this case, I'm willing to rationalize away the factual data in favor of perception."*

This provides an interesting perspective on the analysis of life rafts and this issue at large. Perceptions, regardless of the data, may drive our decisions, especially when it has to do with safety equipment, and leadership.

7b) If large life rafts were removed it would negatively impact our organization's moral. (Airmen would feel that the Air Force is trying to save a buck while putting them and their mission more at risk).

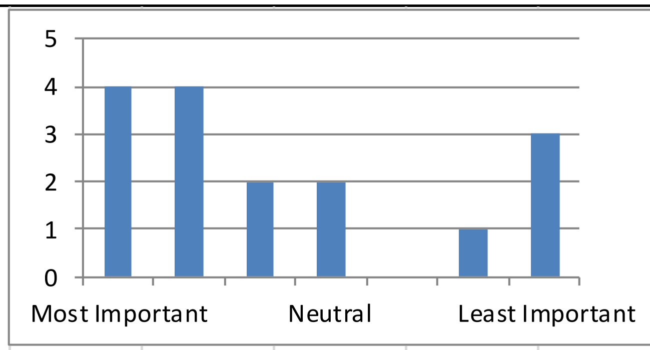


Figure 77. Delphi Round Three, Disparity on Morale

The final question allowed the panel to add any further thoughts regarding the data from all rounds and the study in general. A few panel members discussed perception again and stated that "leadership is all about perceptions. If the troops perceive the commander cares about them the unit is more combat effective." This relates to the last question and connects how perceptions play a critical role to the morale and therefore, work effectiveness of our Airmen. The panel

agreed that the life rafts are a good investment because the money spent on the training, procurement, maintenance, and ferrying the rafts signifies leader's commitment to keep their people safe. Therefore, the life raft is a commitment tool signifying care and loyalty. Although the utility of life rafts is near zero, they perform an alternate function of sustaining high morale and a better force.

Most of the panel members were overall surprised by the results because of the significant differences of opinion on the subject. There were some members who felt there would have been more decisions to remove the life rafts and were glad to see most of the panel judged that the life rafts were needed.

On the other hand, some of the members felt that we cannot rely on "it's always been that way" any longer. And we need to adapt to the changes in our environment. Following past policy because of morale and perceptions is irresponsible, and effectiveness needs to be placed above morale.

Some of the panel members were glad to see the results pointed towards solid knowledge of actual mishaps, understanding of maintenance workload, and the unique Air Force mission.

In summary, the Delphi Method proved to illuminate many different aspects of this study. The insightful comments proved to be the most beneficial in understanding the members thought process. The discussion and points were well received and appreciated. The Delphi Study brought out the many qualitative reasons why life rafts are critical to our Air Force. It helped shape a picture that is more than numbers that the analysis section provided. Managerial implications are discussed next in conclusions and recommendations.

V. Conclusion and Recommendations

The Air Force will need to continue to innovate and bring ideas to the table that will not only sustain or increase our effectiveness but also reduce our overall cost. The Air Force can save money by cutting programs, flight hours, people, or we can become more efficient. Generally, efficiency comes with a capital investment, decrease in flexibility, or an increase in risk. This study concerning the large life rafts on C-5, C-17, C-130, KC-10, and KC-135 has provided a discussion and analysis to a sensitive area of safety. By reducing safety, the Air Force could increase efficiency – but is the risk worth the tradeoff? By removing life rafts, crew and passengers are at a greater risk of drowning in a water incident but the Air Force will see some savings. If we can understand this difficult topic, we not only bring information to it but also clarity to many other cost-saving measures. The Delphi Study was critical in understanding the safety, morale, public opinion, and leadership importance of life rafts to our Air Force. The Analysis was important to understanding the cost and utility of life rafts. The combination of these provides a comprehensive analysis and ultimately answers to the initial research questions.

The analysis section had two main parts. First, the ferrying cost of life rafts and second, the actual percentage of flights requiring life rafts. The Delphi study was completed in three rounds and brought qualitative information regarding the need of large life rafts.

Research Question 1

The first research question asked: What is the rationale to carry large life rafts on the C-5, C-17, C-130, KC-10 and KC-135 and should the policy change based upon a risk assessment

including: chance of ditching/water impact occurrence, severity of occurrence, large life raft utilization capability and probability, and total cost?

Based on the Delphi study the rationale to carry life rafts is for four main reasons. First, life rafts provide the crew and passengers with a safety feature in the event of a water landing. Since the Air Force mission is dynamic and always changing, it is important to maintain this feature. A shift of mission focus to the Pacific highlights the dynamic mission and ever changing requirements for AMC.

Second, the morale of our troops would drop and there would be political consequences of removing these life rafts that outweigh the cost of sustaining the capability. By removing life rafts from the aircraft, the panel believed that airmen would be less productive. This productivity and overall work degradation would cost more to the Air Force than the realized savings of removing life rafts.

Third, one aspect of leadership is to ensure the safety of your people and removing life rafts sends a message to Airmen that saving a “buck” is more important. As previously mentioned, the panel members did believe that the cost-benefit analysis could show that the life rafts should be removed. However, the message sent to the aircrew and passengers was very critical to leadership and morale.

Lastly, the cost to temporarily remove life rafts based on the given mission would have dramatic costs to our force.

In summary, the panel noted that the utility of the life rafts was not as important as the message of safety from the command structure. This indicates that the utility could be zero and yet still a worthwhile feature.

The analysis section shows a net savings of close to $7.7 million for fiscal year 2013 if the life rafts were removed permanently from all of these aircraft. This is not substantial enough to overcome the many points that were brought up in the Delphi study. As many of the panel members stated, there are many other areas of our force that could save money much easier such as the local flight training and simulator usage. The ferrying cost annually does not outweigh the rationale for keeping this equipment on board. However, when calculating this ferrying cost against all the years it presents a different figure. The panel suggested that 16.7 years would pass before the next incident. If this was true, the aggregate cost would be approximately $128 million in order to possibly realize the utility of this safety feature. The panel members also had a range of $.5M to $100M and an average of $25M for the chance to save one life. In the event of a water incident, it is difficult to ascertain the number of passengers that might be saved due to the aircraft load. But if there are more than five members on board the aircraft, the life raft feature is worth the cost of ferrying them in the C-5, C-17, C-130, KC-10, and KC-135 for 16.7 years. However, this does not include the other costs associated with life rafts such as the procurement, training, and maintenance. Additionally, this figure also assumes that the life rafts do save lives and unfortunately history has shown that they do not.

With that said, the C-130 has the least amount of risk, only flying 1% of its sorties over water with passengers. In addition, there are documented cases of a C-130 ditching and the large life rafts not providing any benefit. Due to these reasons, if life rafts were removed permanently, this should be the first airframe.

Related Questions:

Do the policies of carrying life rafts on the aircraft provide the safety to our Airmen that we deem critical?

In order to answer this question it is important to understand the previous ditching events, the risk of each aircraft flying over water with passengers, and the technical aspects of each aircraft.

The C-130 and KC-135 have ditched, but the C-130 is the only known aircraft to have ditched and had survivors. The other aircraft in this study has yet to ditch or utilize the life rafts in an actual water emergency.

The C-5 aircraft is the largest aircraft in the inventory and there are no previous incidents that reveal its ditching and life raft employment capability. The technical orders require that the main landing gear to be down upon ditching which is different than the other aircraft but also states that the integrity of the aircraft will sustain a water impact and provide ample time for passengers and crew to exit the aircraft before the aircraft sinks. Furthermore, the life rafts are placed near the exits. The exit locations are also spread about the aircraft and provide multiple options. Passengers are also at the top portion of the aircraft providing more distance from incoming water.

The C-5 flies about 24% of all of its flights overwater with passengers. Therefore, the C-5 mission is at a greater risk and need of life rafts. Based on the technical orders and over flight analysis, the C-5 exit and life raft employment capability does provide the safety deemed critical.

The C-17 does not have any past water incidents to draw conclusions from, but based on the technical orders the C-17 should withstand a water impact and float long enough to allow the exit of the crew and passengers. The placement of the life rafts is not at the exits of the aircraft,

but it does provide two large life rafts in front of the leading edge of the wing and one in the aft section of the aircraft. This capability should provide the crew or passengers additional safety if the hull split or the mid to aft section of the aircraft was thoroughly damaged or on fire. The exit capability of the aircraft is more difficult because passengers are located on the floor of the aircraft. Therefore, passengers would likely be overwhelmed by incoming water. The ladder provided does drop down, but in the event of an emergency, many passengers would be stuck in the hull of the aircraft unable to exit.

The C-17 flies about 11% over water with passengers thus having a relatively low risk of a water incident needing multiple life rafts. Based on this information the C-17 does not provide the safety deemed critical with its evacuation and life raft capability.

The C-130 has shown that the life rafts do not provide the safety feature that is needed to save passenger and crew members lives. The placement of the life rafts has led to the life rafts not surviving the crash or being destroyed once employed rendering it useless. The C-130 hull is also not designed to withstand the impact of a ditching event, limiting the ability of any passenger to exit or survive after impact. The crew area has withstood the initial impact and exited successfully but only to use smaller rafts or seat cushions to survive for a short period.

The C-130 flies over the water with passengers and only need life rafts approximately 1% of all of its flights. The C-130 is thus at a reduced risk of ever needing this equipment. Based on this information, the C-130 does not provide the safety needed to sustain life after a water landing.

The KC-10 has not ditched or had a water incident. The life rafts are part of the exit and are dual employed with a slide. The rafts placement on the KC-10 offers multiple locations on the aircraft for passengers and crew to evacuate ensuring a wide range of possible scenarios.

Based on the technical orders the aircraft should stay intact after impact and provide ample time for exit.

The KC-10 flies about 17% of its flights overwater with passengers. The KC-10 life raft and ditching capability does meet the level of safety deemed critical.

The KC-135 has yet to survive a ditching event so the utility of large life rafts are unknown. The KC-135 life rafts are employed differently than the other aircraft. They are positioned by the exits but the exits are either over the wing or in the aft section of the aircraft. Furthermore, the life rafts are manually ejected once outside the aircraft.

The KC-135 flies approximately 59% of its flights over water with passengers. Based on the technical orders, past incidents, and risk assessment the KC-135 does not provide the level of safety deemed critical to sustain life after a water landing.

In conclusion, the policy to keep life rafts on board these aircraft should remain based upon the results of the Delphi Study. However, each aircraft should be looked at individually. The C-17 and C-130 should re-evaluate their exit capability for passengers in the hull of the aircraft. The C-130 and KC-135 should examine and enhance its life raft employment.

Limitations

There are multiple limitations to this study. First, the study is not generalizable. Although there was a wide range of participants in the Delphi study it did not include all fields or the number of participants needed to obtain a more comprehensive study. The study was limited to 20 participants and for the most part there were approximately 17 participants.

The second limitation dealt with a limited amount of data regarding ditching events. Although this is a good thing it does make the study much more difficult to illustrate examples in which we can learn from.

Conducting a Delphi study is extremely difficult for multiple reasons that became limits for this study. First, as a single researcher developing the questions, analyzing the results, and providing the next rounds questions objectivity was not checked. If there were multiple members in the development team, the questions, answer analysis and future rounds would be subjected to more scrutiny and less bias leading to a more panoptic study.

The Delphi study is a great way to hear all the voices of the experts, but it also limits the feedback between members during a discussion. This limitation of the study does not provide an in-depth analysis of individual responses and counter arguments that may ultimately persuade members differently based on opinions or data from other individuals.

The analysis was limited by technology and the amount of data. Dealing with close to a half million data points each containing 23 variables makes it very difficult to sort, compute and analyze. The data was therefore reduced to only a few variables losing some information that would have provided additional insight to the analysis section.

Determining if a flight was over water was also limited based upon the assumptions and technology. First, the flight was deemed to be over large bodies of water by analyzing it on an electronic map and its included distance ruler. It is very possible that some flights are considered over water flights that were not captured, and the alternative is also true. In addition, if a flight deviated from its origin to destination circular route, it would not show in this data.

Future Research

Future research should be conducted in three different fields in order to complete this study: 1) In depth structural engineering study on the effect of a water landing to these aircraft and the consequences to the positioning and employment of both exits and life rafts, 2) Study of the cost to maintain, procure, and train our force on the use of life rafts, and 3) Analysis of the true impact to the morale and political consequences of removing life rafts from these aircraft.

Each of the aircraft in this study has different life rafts sizes and different exiting, ditching, and life raft employment procedures. Understanding which aircraft performs the best in a ditching situation would be important for future acquisitions and enhancements to our current aircraft.

The procurement, training, and maintenance cost of this equipment is also very substantial. The maintenance cost includes the removing, replacing, inspecting, training, and buildings to facilitate. The life rafts are also not cheap to procure or replace. The cost to purchase a life raft can exceed $56,000 (CMM 25-62-04, 2013). Furthermore, life rafts removed for inspection are sometimes damaged and replaced. These costs would provide additional information to leaders that is important in evaluating the utility of having large life rafts on the C-5, C-17, C-130, KC-10, and KC-135.

Lastly, a study that investigates the true political consequences to the removal of life rafts. If we could truly answer the following questions, leaders would have a more definitive approach to making difficult decisions. How would Airmen react to the removal of life rafts? Would it have an impact on the morale and how would that translate to the Air Force's ability to affect the mission? How would the families and U.S. population react to the removal of life rafts, and how

would media capture this story? By better understanding the answers to these questions it would be easier to weigh the overall decision.

In summary, the decision to remove life rafts from the aircraft in this study would not be a prudent decision. The social impact outweighs the potential savings that could result. However, it is imperative as leaders to look at these types of situations objectively so that the total safety of our Airmen is not compromised because of the appearance and political ramifications of a choice. As aircraft reliability improves, and other infrastructure systems are in place there is a time that life rafts should be removed from aircraft. There are many other safety issues that if addressed with funds and attention will ultimately provide a safer environment for our force.

Appendix A: Round One

Questionnaire #1: Initial Survey

At what cost do we mitigate risk enough: a discussion on large life rafts on Air Mobility's Aircraft

You are receiving this questionnaire as a mobility expert, Air Force Senior leader or direct customer of the Air Mobility Command and Control Enterprise. *The purpose of this research is to conduct a qualitative study in an effort to better understand senior level officials and subject matter expert's opinions on the role of addressing risk in regards to large life rafts and the safety benefit they provide to passengers and crewmembers.* By responding, **you have the unique opportunity to take part in a discussion that will provide an analysis that will shape future discussions in a constrained monetary environment.**

Background: Because each respondent will have a different perspective, here is a brief overview of the study topic.

For flight paths that exceed 50 miles from the coastline, the Federal Aviation Administration (FAA) mandates the following: 1) that aircraft be equipped with large life rafts to handle 150% of the passenger load, 2) that a survival bag containing equipment be available per large life raft, and 3) that aircrew be trained to handle this equipment. Due to these rules the Air Mobility Command's Major Weapon Systems: KC-135, C-130, C-17, C-5 and KC-10 carry multiple sets of large life rafts and water survival kits that weigh approximately 300 pounds per set.

As our large aircraft are modified with better engines, electronics, and equipment that improve their performance and reliability, safety equipment is used less frequently. Considering this increase in safety performance, this Delphi study will reevaluate the financial costs, opportunity costs, and utility of the large life rafts. The questions in this study will examine how the Air Force views safety and accepts risk. (This study focusses only on large life rafts such as the 20-man and 46-man life rafts. It does not address the use of individual life rafts, seat cushions, or any other floatation device.)

The data obtained through this study will form recommendations offered to decision-makers at Air Mobility Command and Air Force Institute of Technology. This is not just a typical survey but rather Delphi study. The reason I chose a Delphi study is because this research problem does not lend itself to a simple survey. The Delphi method is an iterative, group communication process which is used to collect and distill the judgments of experts using a series of questionnaires interspersed with group feedback. You, as a panel member, embody the diverse backgrounds with respect to experience and expertise. There will be 2-3 surveys that will change based on the answers that you provide.

Please note the following:

<u>Benefits and risks:</u> There are no personal benefits or risks for participating in this study. Your participation in completing this questionnaire should take less than 15 minutes per round.

<u>Confidentiality:</u> Questionnaire responses are confidential. Your identity will not be associated with any responses you give in the final research report. No individual data will be reported; only data in aggregate will be made public. I understand that the names and associated data I collect must be protected at all times, only be known to the researcher, and managed according to the Air Force Institute of Technology (AFIT) interview protocol. At the conclusion of the study, all data will be turned over to the advisor and all other copies will be destroyed.

<u>Voluntary consent:</u> Your participation in this study is completely voluntary. You have the right to decline to answer any question, to refuse to participate or to withdraw at any time. Your decision of whether or not to participate will not result in any penalty or loss of benefits to which you are otherwise entitled. Completion of the questionnaire implies your consent to participate.

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The sponsor for this research is Colonel Bobby Fowler, the Director of the Fuel Efficiency Office, at Air Mobility Command Scott Air Force Base, Illinois.

Process:
1. Please complete this survey **electronically** and return it to: **jason.anderson.4@us.af.mil** as soon as possible but no later than **22 January 2012.** If you have questions, I can be reached at CELL 325-725-3683 or via DSN 754-7740.

2. This questionnaire is an instrument of a Delphi study. The questionnaires are designed to focus on problems, opportunities, solutions or forecasts. Each questionnaire is developed based on the group results of the previous questionnaire. The process continues until the research question is ultimately answered. For example, when consensus is reached or sufficient information has been exchanged. This on average takes three to four rounds with the panel. There are five primary questions for this round. Again, the questionnaire is non-attribution, so please elaborate fully on your answers. Subsequent rounds will be announced as needed and all research will conclude by March 2012.

Research questions:
Please answer the following questions as clearly and concisely as possible without omitting critical information required for the group to consider your opinions. **The large life rafts are those among the 5 Major Weapon Systems that include the C-5, C-17, C-130, KC-10 and KC-135 and are at least as large as the 20-Man life raft. The study does not address changes to other types of floatation on aircraft, such as the single-man life rafts.**

Background questions:

1. Personal Information:
    a. Name:
    b. Rank/Grade:
    c. Current Duty Title:
    d. Time in Current Duty Position:
    e. Core AFSC/MOS/Primary Duty Code:

2. What experience do you have with large life rafts and their use on large aircraft?

3. On a scale from 1 to 5 (1-strongly disagree, 3-neither agree/disagree, 5-strongly agree), please assess the statement, "Large life-rafts (20-man or greater) are essential to the safety of our Airmen flying the C-5, C-17, C-130, KC-10 and KC-135" please elaborate on your response.

To the best of your ability, please answer the below questions based on the general practices of your department or organization.

1. What do you believe were the driving factors for putting large life rafts on board the KC-135, C-17, KC-10, C-5, or C-130?
2. Do you believe that these driving factors have changed today? If so which ones and why?
3. If large life rafts were removed from large aircraft within the military (waiver approved by FAA/ICAO), what would be your top concerns?
4. If large life rafts were removed from large aircraft within the military (waiver approved by FAA/ICAO), what would be the top benefits?
5. Do you believe that the benefits outweigh your top concerns? Why or why not?
6. In the past 10 years, parachutes were removed from the KC-135, C-17, KC-10, C-5, and C-130 aircraft. Do you believe the removal of parachutes from the mobility aircraft would be comparable to removing large life rafts from these same aircraft? Why or why not?
7. If you have any other thoughts that you would like to share on keeping or removing large life rafts please share in this section.

Appendix B: Round Two

Questionnaire #2: Quantifying Results

At what cost do we mitigate risk enough: a discussion on large life rafts on Air Mobility's Aircraft

You are receiving this questionnaire as a mobility expert, Air Force Senior leader or direct customer of the Air Mobility Command and Control Enterprise. *The purpose of this research is to conduct a qualitative study in an effort to better understand senior level officials and subject matter expert's opinions on the role of addressing risk in regards to large life rafts and the safety benefit they provide to passengers and crewmembers.* By responding, **you have the unique opportunity to take part in a discussion that will provide an analysis that will shape future discussions in a constrained monetary environment.**

Background: Because each respondent will have a different perspective, here is a brief overview of the study topic.

For flight paths that exceed 50 miles from the coastline, the Federal Aviation Administration (FAA) mandates the following: 1) that aircraft be equipped with large life rafts to handle 150% of the passenger load, 2) that a survival bag containing equipment be available per large life raft, and 3) that aircrew be trained to handle this equipment. Due to these rules the Air Mobility Command's Major Weapon Systems: KC-135, C-130, C-17, C-5 and KC-10 carry multiple sets of large life rafts and water survival kits that weigh approximately 300 pounds per set.

As our large aircraft are modified with better engines, electronics, and equipment that improve their performance and reliability, safety equipment is used less frequently. Considering this increase in safety performance, this Delphi study will reevaluate the financial costs, opportunity costs, and utility of the large life rafts. The questions in this study will examine how the Air Force views safety and accepts risk. (This study focusses only on large life rafts such as the 20-man and 46-man life rafts. It does not address the use of individual life rafts, seat cushions, or any other floatation device.)

The data obtained through this study will form recommendations offered to decision-makers at Air Mobility Command and Air Force Institute of Technology. This is not just a typical survey but rather Delphi study. The reason I chose a Delphi study is because this research problem does not lend itself to a simple survey. The Delphi method is an iterative, group communication process which is used to collect and distill the judgments of experts using a series of questionnaires interspersed with group feedback. You, as a panel member, embody the diverse backgrounds with respect to experience and expertise. There will be 2-3 surveys that will change based on the answers that you provide.

Please note the following:

<u>Benefits and risks:</u> There are no personal benefits or risks for participating in this study. Your participation in completing this questionnaire should take less than 15 minutes per round.

<u>Confidentiality:</u> Questionnaire responses are confidential. Your identity will not be associated with any responses you give in the final research report. No individual data will be reported; only data in aggregate will be made public. I understand that the names and associated data I collect must be protected at all times, only be known to the researcher, and managed according to the Air Force Institute of Technology (AFIT) interview protocol. At the conclusion of the study, all data will be turned over to the advisor and all other copies will be destroyed.

<u>Voluntary consent:</u> Your participation in this study is completely voluntary. You have the right to decline to answer any question, to refuse to participate or to withdraw at any time. Your decision of whether or not to participate will not result in any penalty or loss of benefits to which you are otherwise entitled. Completion of the questionnaire implies your consent to participate.

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The sponsor for this research is Colonel Bobby Fowler, the Director of the Fuel Efficiency Office, at Air Mobility Command Scott Air Force Base, Illinois.

Process:
1. Please complete this survey **electronically** and return it to: **jason.anderson.4@us.af.mil** as soon as possible but no later than **4 March 2013.** If you have questions, I can be reached at CELL 325-725-3683 or via DSN 754-7740.

2. This questionnaire is an instrument of a Delphi study. The questionnaires are designed to focus on problems, opportunities, solutions or forecasts. Each questionnaire is developed based on the group results of the previous questionnaire. The process continues until the research question is ultimately answered. For example, when consensus is reached or sufficient information has been exchanged. This on average takes three to four rounds with the panel. There are five primary questions for this round. Again, the questionnaire is non-attribution, so please elaborate fully on your answers. Subsequent rounds will be announced as needed and all research will conclude by March 2012.

Research questions:
Please answer the following questions as clearly and concisely as possible without omitting critical information required for the group to consider your opinions. **The large life rafts are those among the 5 Major Weapon Systems that include the C-5, C-17, C-130, KC-10 and KC-135 and are at least as large as the 20-Man life raft. The study does not address changes to other types of floatation on aircraft, such as the single-man life rafts.**

To the best of your ability, please answer the below questions based on the general practices of your department or organization.

1. On a scale from 1 to 5 (1-strongly disagree, 3-neither agree/disagree, 5-strongly agree), please assess the statement, "The US Airline Flight 1549 that crashed into the Hudson river changed my mind on large life raft requirements to be carried over land in addition to over water."

If you like please elaborate on your response.

2. In future operations of the C-130, KC-10, C-5, KC-135, or C-17 I think there will be a water incident every ___ years on average. (Fill in the blank)

Forecast, X is the value that you assessed in question #2	Rank Order from 1 to 4 1=Most probable 4=least probable
A water landing will occur in the next X years and large life rafts will save lives	
A water incident will occur in the next X years but the crew and passengers will not survive the impact	
A water landing will occur in the next X years but large life rafts will be destroyed or unusable	
A water landing will not occur	

Policy guidance	Rank Order from 1 to 7 1=Most important 7=least important
Large life raft removal could only be implemented on missions without passengers or flights over land. Therefore, large life rafts would have to be continually removed and replaced creating a major problem for our workforce and mission.	
As aircraft become more reliable, we should consider removing large life rafts from our aircraft flying over water in non-combat zones.	
Our large mobility aircraft face threats different from commercial airlines. These threats necessitate life rafts on our aircraft.	
A cost benefit analysis of removing life rafts could show that they are a poor investment for achieving safety.	
If the FAA's policy did not require large-life rafts, the Air Force should consider removing the large life rafts.	
A water landing will occur in the next ten years and large life rafts will save lives	
If large life rafts were removed it would negatively impact our organization's moral. (Airmen would feel that the Air Force is trying to save a buck while putting them and their mission more at risk).	

Air Force Safety has a very challenging job. They must make decisions to cut or fund safety programs based on many factors but ultimately trying to save as many lives as possible within their budget. If you were put into this position, at what point would you think it is a wise decision to reevaluate large-life rafts on our large mobility aircraft? How much would you pay for the *chance* to save one life?

Loss of one life										
.25M	.5M	.75M	1M	1.5M	2M	5M	10M	50M	100M	>100M

Appendix C: Round Three

Questionnaire #3: Quantifying Results
At what cost do we mitigate risk: a discussion on large life rafts on Air Mobility's Aircraft

You are receiving this questionnaire as a mobility expert, Air Force Senior leader or direct customer of the Air Mobility Command and Control Enterprise. *The purpose of this research is to conduct a qualitative study in an effort to better understand senior level officials and subject matter expert's opinions on the role of addressing risk in regards to large life rafts and the safety benefit they provide to passengers and crewmembers.* By responding, **you have the unique opportunity to take part in a discussion that will provide an analysis that will shape future discussions in a constrained monetary environment.**

Background: Because each respondent will have a different perspective, here is a brief overview of the study topic.

For flight paths that exceed 50 miles from the coastline, the Federal Aviation Administration (FAA) mandates the following: 1) that aircraft be equipped with large life rafts to handle 150% of the passenger load, 2) that a survival bag containing equipment be available per large life raft, and 3) that aircrew be trained to handle this equipment. Due to these rules the Air Mobility Command's Major Weapon Systems: KC-135, C-130, C-17, C-5 and KC-10 carry multiple sets of large life rafts and water survival kits that weigh approximately 300 pounds per set.

As our large aircraft are modified with better engines, electronics, and equipment that improve their performance and reliability, safety equipment is used less frequently. Considering this increase in safety performance, this Delphi study will reevaluate the financial costs, opportunity costs, and utility of the large life rafts. The questions in this study will examine how the Air Force views safety and accepts risk. (This study focusses only on large life rafts such as the 20-man and 46-man life rafts. It does not address the use of individual life rafts, seat cushions, or any other floatation device.)

The data obtained through this study will form recommendations offered to decision-makers at Air Mobility Command and Air Force Institute of Technology. This is not just a typical survey but rather Delphi study. The reason I chose a Delphi study is because this research problem does not lend itself to a simple survey. The Delphi method is an iterative, group communication process which is used to collect and distill the judgments of experts using a series of questionnaires interspersed with group feedback. You, as a panel member, embody the diverse backgrounds with respect to experience and expertise. There will be 2-3 surveys that will change based on the answers that you provide.

Please note the following:
Benefits and risks: There are no personal benefits or risks for participating in this study. Your participation in completing this questionnaire should take less than 15 minutes per round.

Confidentiality: Questionnaire responses are confidential. Your identity will not be associated with any responses you give in the final research report. No individual data will be reported; only data in aggregate will be made public. I understand that the names and associated data I collect must be protected at all times, only be known to the researcher, and managed according to the Air Force Institute of Technology (AFIT) interview protocol. At the conclusion of the study, all data will be turned over to the advisor and all other copies will be destroyed.

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Process:
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2. This questionnaire is an instrument of a Delphi study. The questionnaires are designed to focus on problems, opportunities, solutions or forecasts. Each questionnaire is developed based on the group results of the previous questionnaire. The process continues until the research question is ultimately answered. For example, when consensus is reached or sufficient information has been exchanged. This on average takes three to four rounds with the panel. There are five primary questions for this round. Again, the questionnaire is non-attribution, so please elaborate fully on your answers. Subsequent rounds will be announced as needed and all research will conclude by March 2012.

Research questions:
Please answer the following questions as clearly and concisely as possible without omitting critical information required for the group to consider your opinions. **The large life rafts are those among the 5 Major Weapon Systems that include the C-5, C-17, C-130, KC-10 and KC-135 and are at least as large as the 20-Man life raft. The study does not address changes to other types of floatation on aircraft, such as the single-man life rafts.**

To the best of your ability, please answer the below questions based on the general practices of your department or organization.

The group results and your scores are depicted below in figure 1, and 2

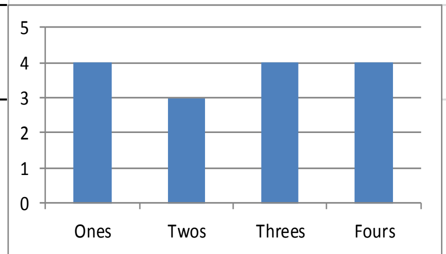
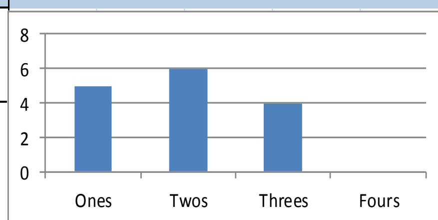
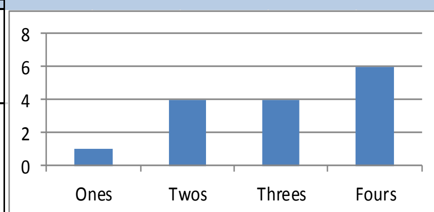
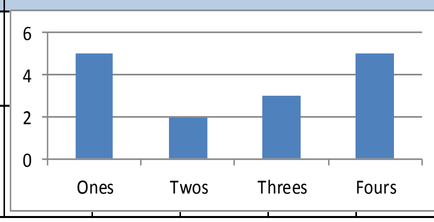
1. I paraphrased the overall views in the below paragraph. Do you agree with this statement? Do you have any additional remarks that you have not already provided?

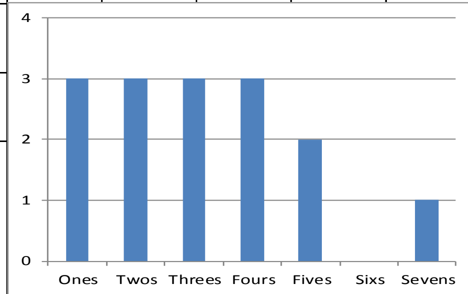
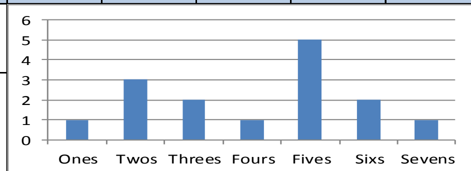
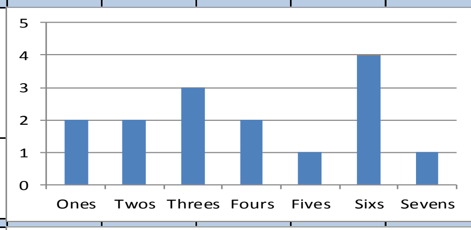
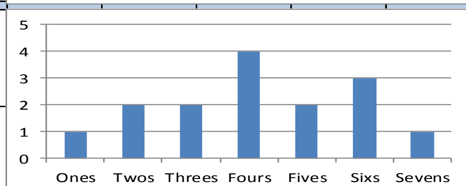
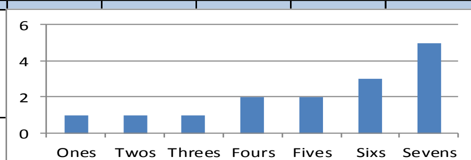
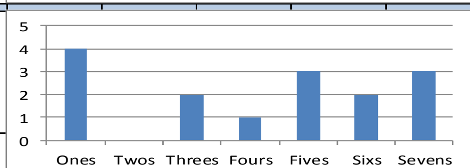
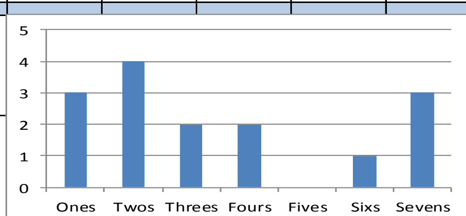
Large life rafts are critical to the safety and morale of our Airmen. Additionally, the labor, cost, and loss of flexibility from removing them are too significant. Even if aircraft reliability or aircraft performance increased, the cost-benefit analysis would not change my mind on removing large life rafts. Although regulatory, the FAA requirements are least significant in our decision process to carry life rafts because we would transport them regardless of their rules.

2. The answer to questions 1a and 4a in figure 1 had the greatest disparity. Your answer was X, what are your thoughts on the differing opinions?
    a. In your opinion, does this also answer the disparity in question 6b in figure 2?

3. The answers to question 7b received the most top answers. However, question 7b also received many low rankings giving it an overall depressed average score. You answered X, what thoughts do you have on this disparity?

4. Do you have any other thoughts on the results that you would like to share?

Forecast	Rank Order 1=Most Probable 4=Least Probable		Rank
1a. A water landing will occur in the next X years and large life rafts will safe lives	Group-Average: 2.53 Group Std Dev: 1.19 Group Mode:1,3,4		Avg: 2 (Tie)
	Your Score:		Mode: Tie 1, 3, 4
2a. A water incident will occur in the next X years but the crew and passengers will not survive the impact	Group-Average: 1.93 Group Std Dev: .8 Group Mode: 2		Avg: 1
	Your Score:		Mode: 2
3a. A water landing will occur in the next X years but large life rafts will be destroyed or unusable	Group-Average: 3 Group Std Dev: 1 Group Mode: 4		Avg:4
	Your Score:		Mode: 4
4a. A water landing will not occur	Group-Average: 2.53 Group Std Dev:1.3 Group Mode:1,4		Avg: 2 (Tie)
	Your Score:		Mode: 1, 4

			Rank
Policy guidance	Rank Order 1= Most Important 7=Least Important		
1b. Large life raft removal could only be implemented on missions without passengers or flights over land. Therefore, large life rafts would have to be continually removed and replaced creating a major problem for our workforce and mission.	Group-Average: 3.133 Group Std Dev:1.73 Group Mode:1-4 Your Score:		Avg: 1 Mode: Tie 1-4
2b. As aircraft become more reliable, we should consider removing large life rafts from our aircraft flying over water in non-combat zones.	Group-Average:4.07 Group Std Dev:1.8 Group Mode:5 Your Score:		Avg: 4 Mode: 5
3b. Our large mobility aircraft face threats different from commercial airlines. These threats necessitate life rafts on our aircraft.	Group-Average: 3.93 Group Std Dev:1.98 Group Mode:6 Your Score:		Avg:3 Mode: 6
4b. A cost benefit analysis of removing life rafts could show that they are a poor investment for achieving safety.	Group-Average:4.13 Group Std Dev:1.73 Group Mode:4 Your Score:		Avg: 5 Mode: 4
5b. If the FAA's policy did not require large-life rafts, the Air Force should consider removing the large life rafts.	Group-Average: 5.13 Group Std Dev:1.96 Group Mode:7 Your Score:		Avg: 7 Mode: 7
6b. A water landing will occur in the next ten years and large life rafts will save lives	Group-Average: 4.13 Group Std Dev: 2.32 Group Mode: 1 Your Score:		Avg: 5 Mode: 1
7b. If large life rafts were removed it would negatively impact our organization's moral. (Airmen would feel that the Air Force is trying to save a buck while putting them and their mission more at risk).	Group-Average: 3.47 Group Std Dev: 2.3 Group Mode:2 Your Score:		Avg: 2 Mode: 2

Appendix D: Google Earth C-5, C-17, C-130, KC-10, KC-135 Flights

C-5

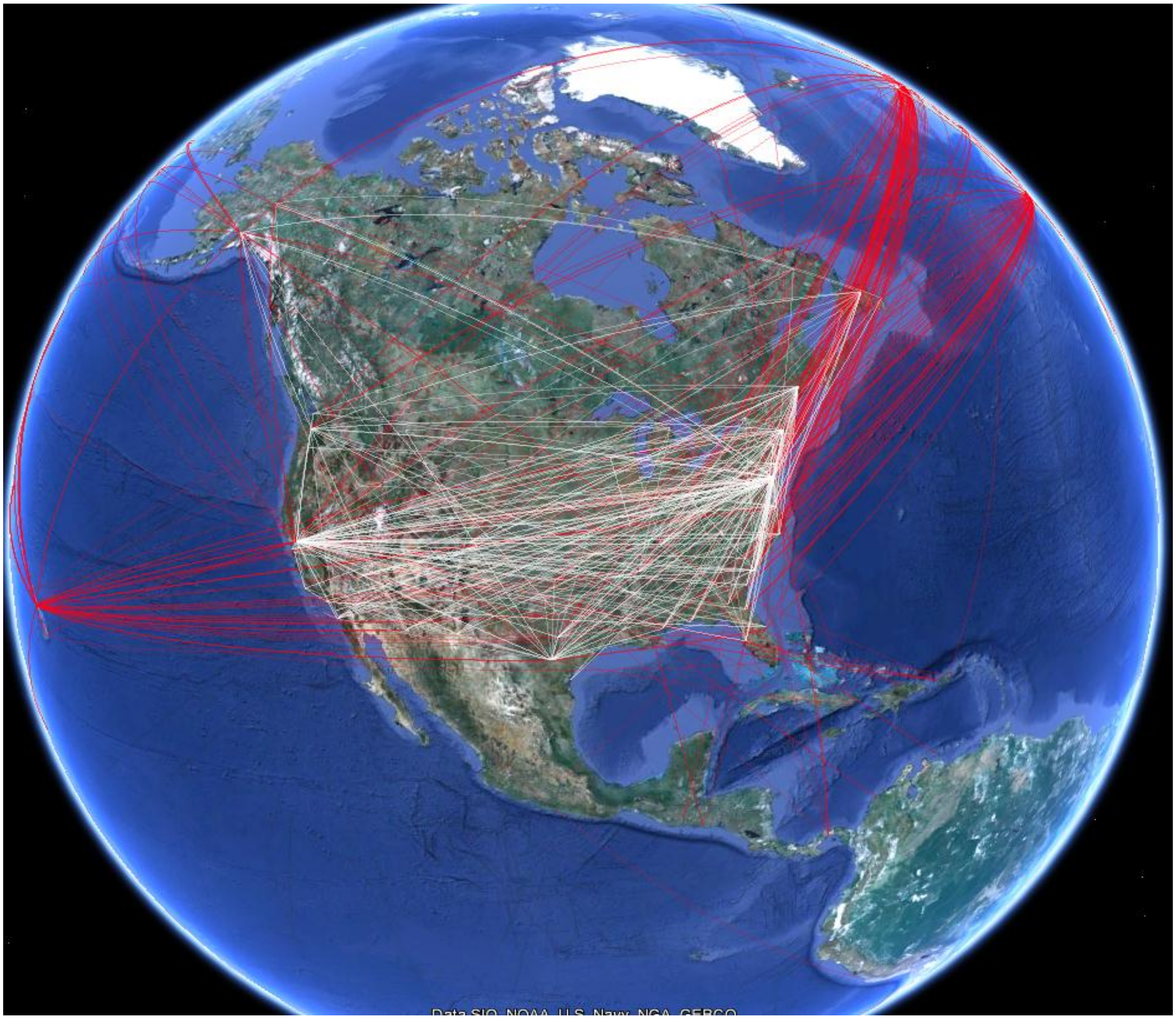


Figure 78. Google Earth, C-5 Flights with Passengers from Oct 2009-March 2013. Americas

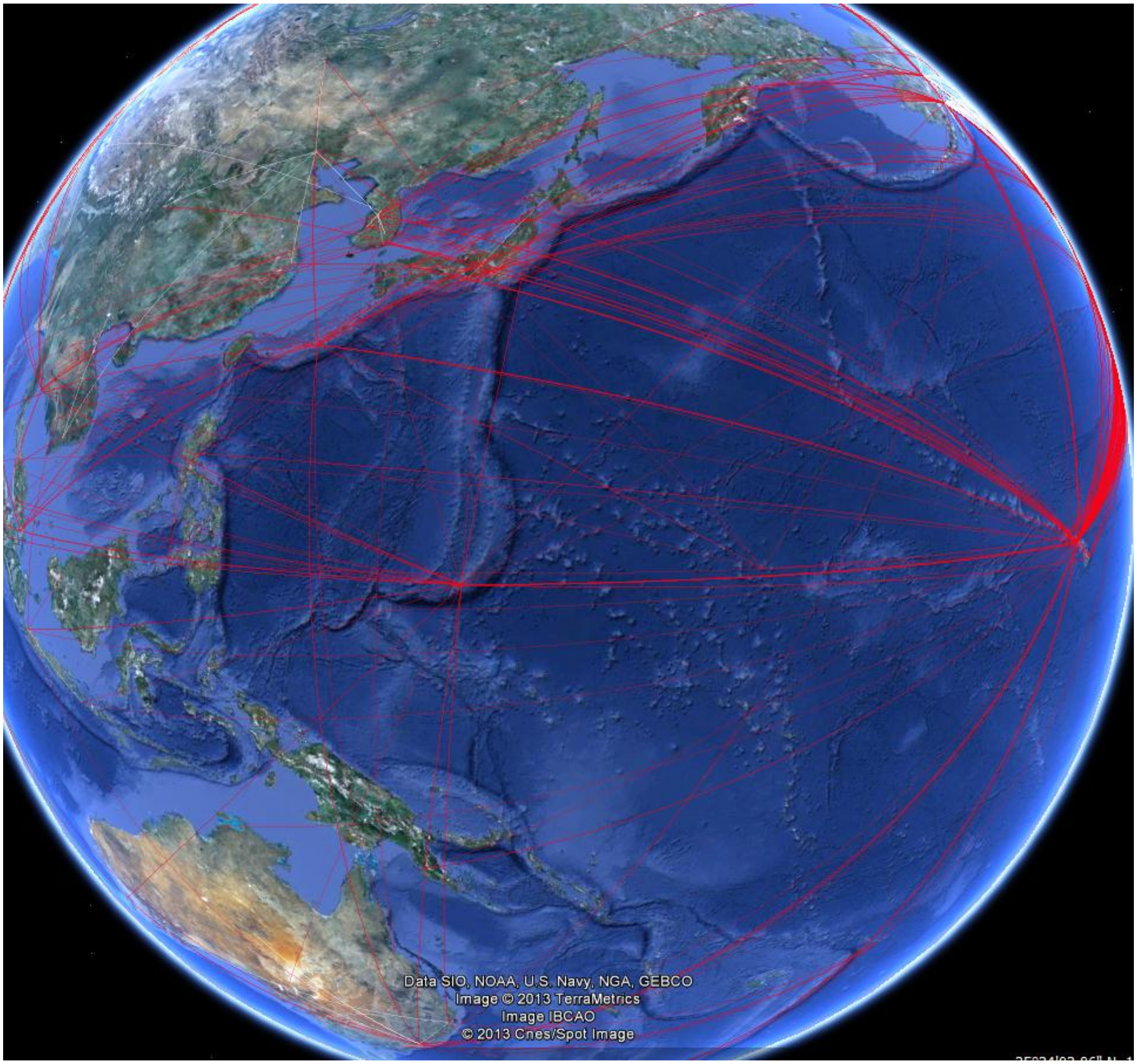


Figure 79. Google Earth, C-5 Flights with Passengers from Oct 2009-March 2013 Pacific

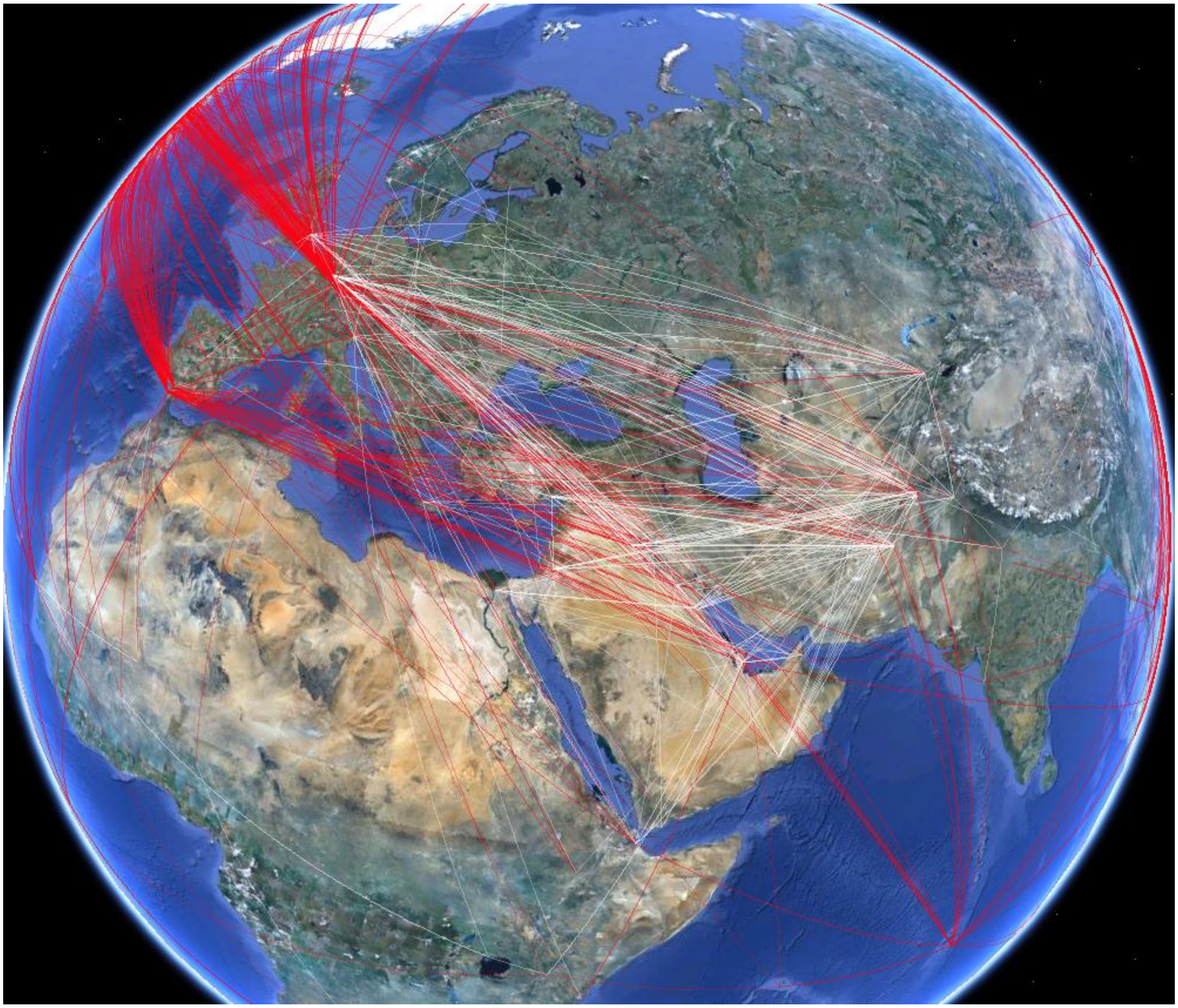


Figure 80. Google Earth, C-5 Flights with Passengers from Oct 2009-March 2013 Southwest Asia

C-17

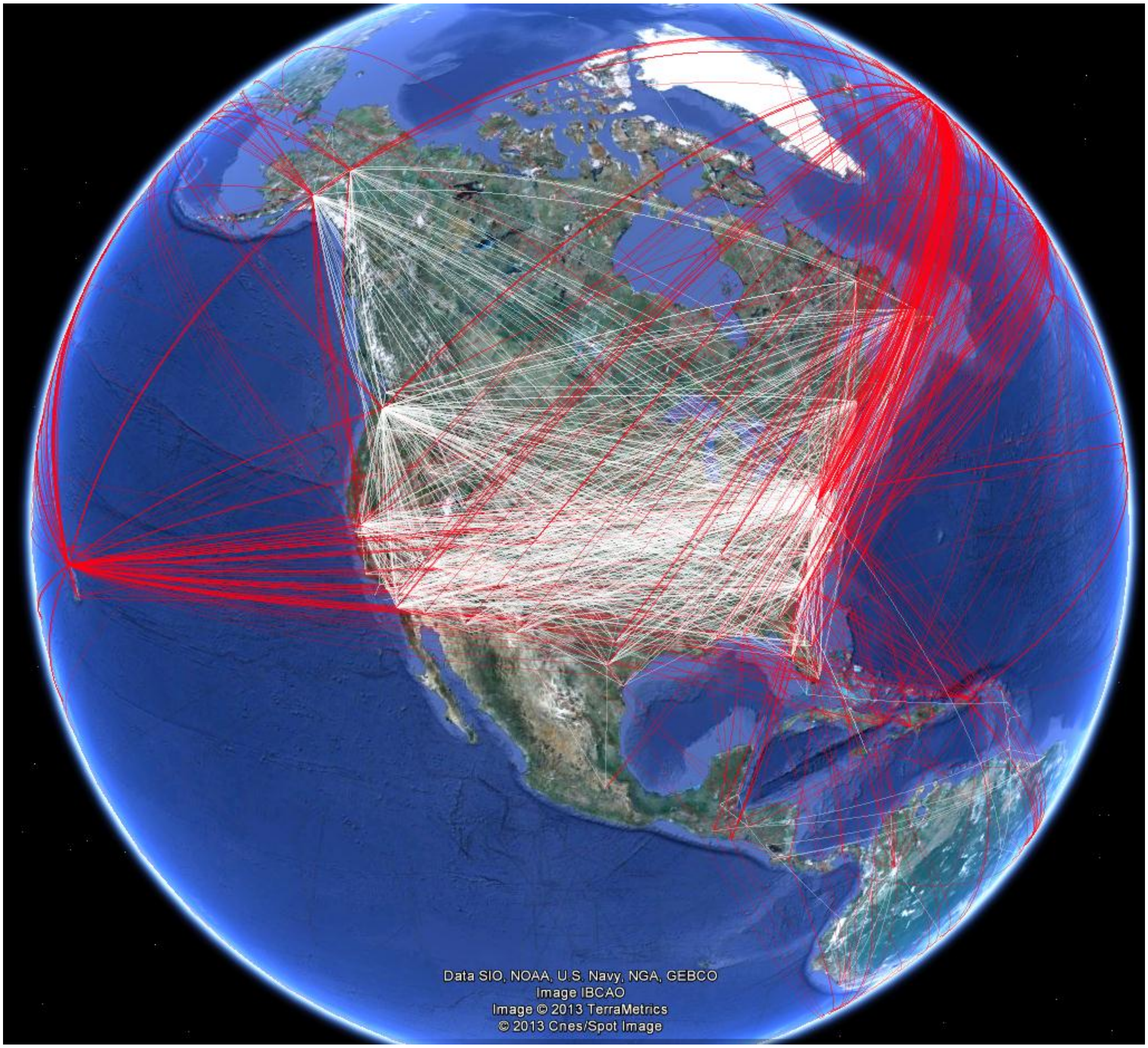

Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image IBCAO
Image © 2013 TerraMetrics
© 2013 Cnes/Spot Image

Figure 81. C-17 Flights with Passengers From October 2009 to March 2013. Americas

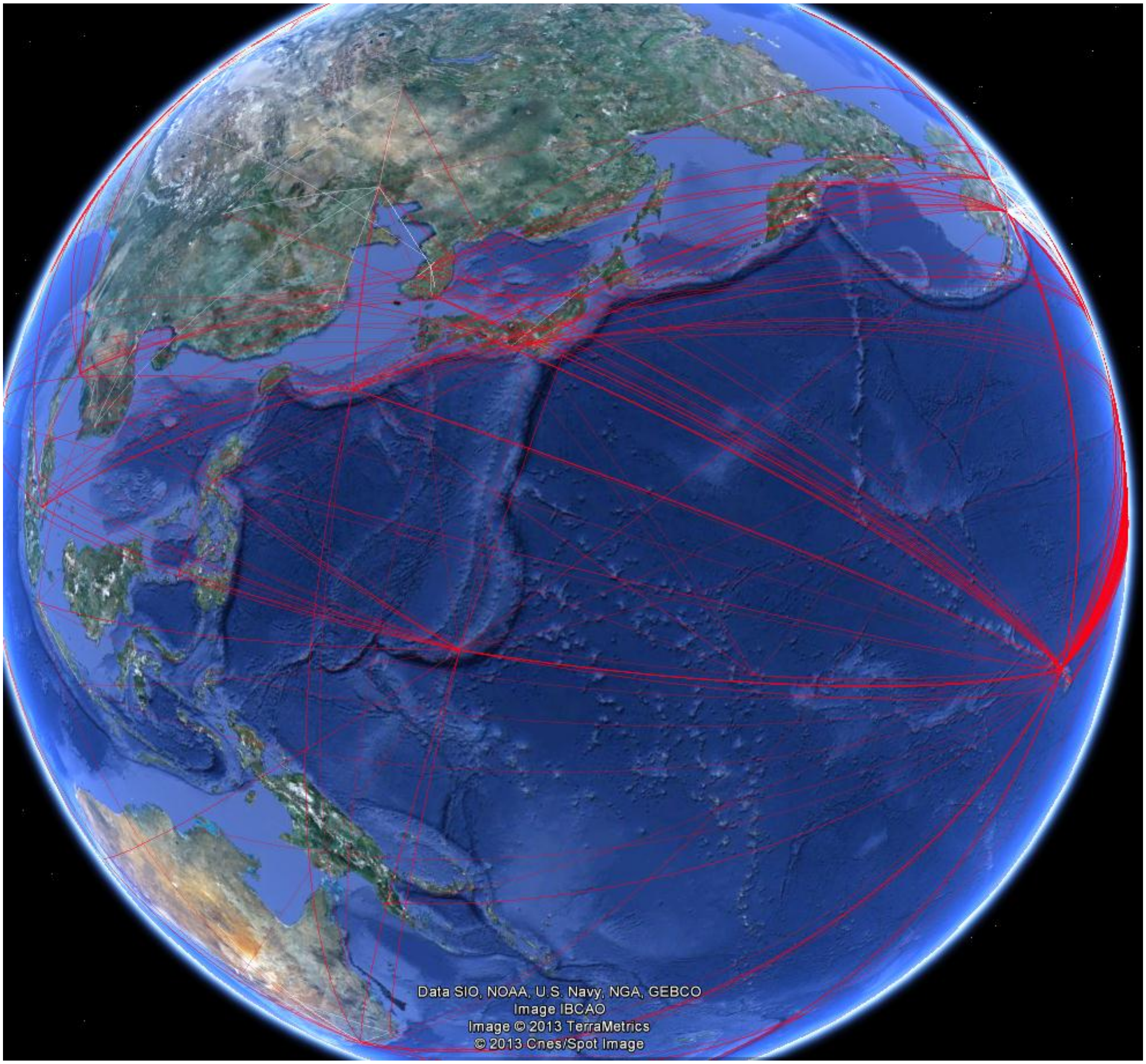


Figure 82. C-17 Flights with Passengers From October 2009 to March 2013. Pacific

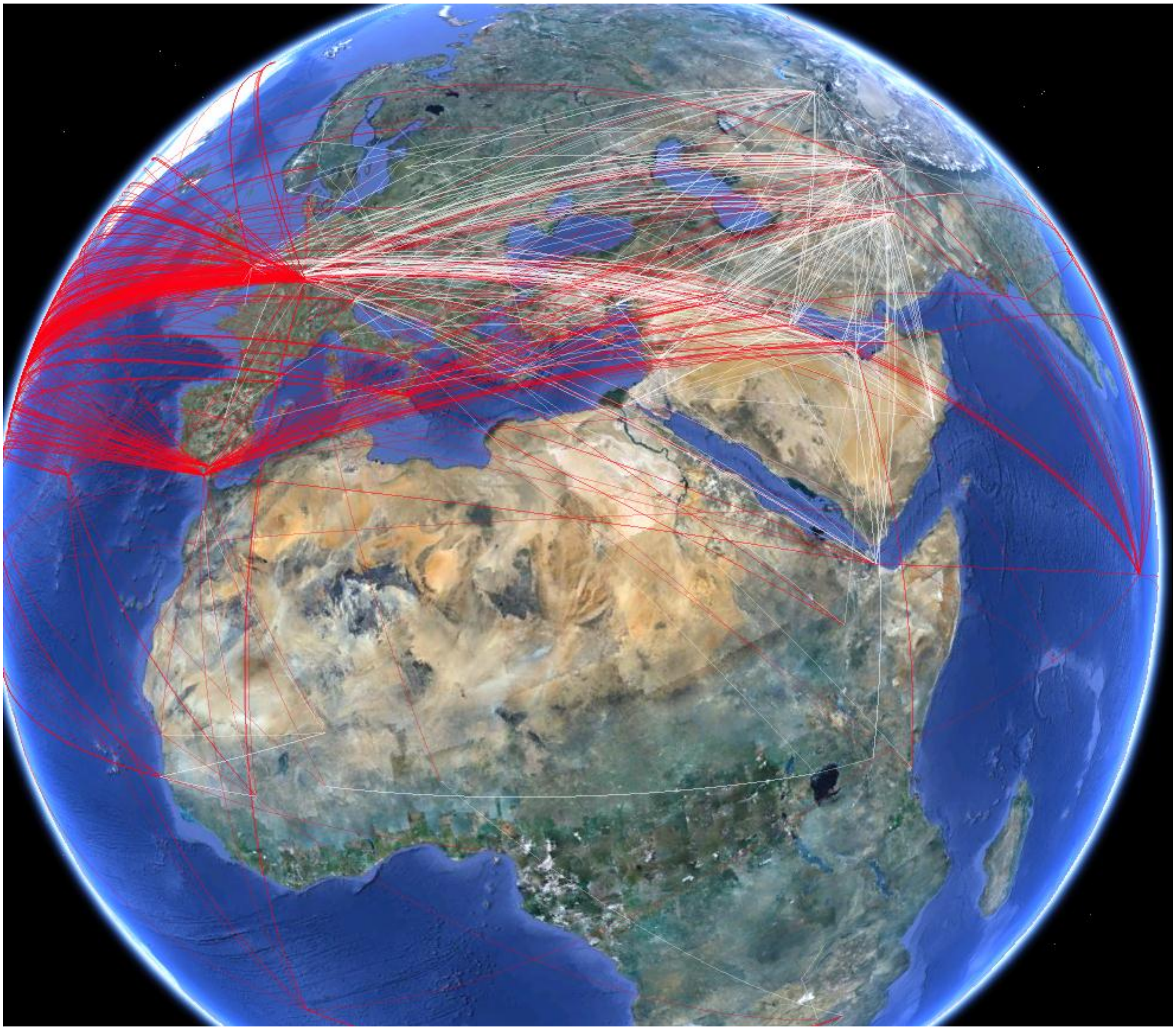


Figure 83. C-17 Flights with Passengers From October 2009 to March 2013. Southwest Asia

C-130

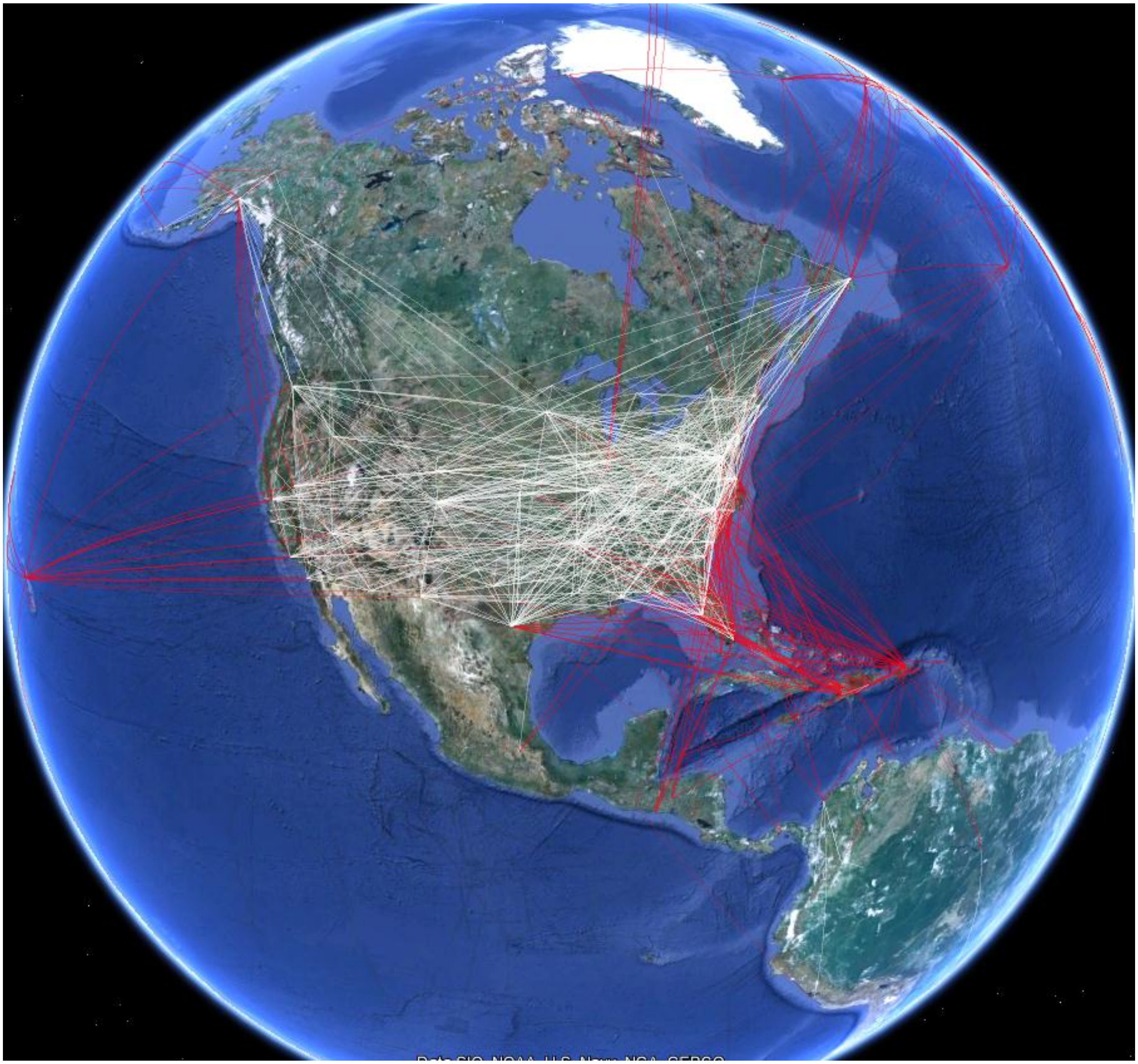


Figure 84. C-130 Flights with Passengers From October 2009 to March 2013. Americas

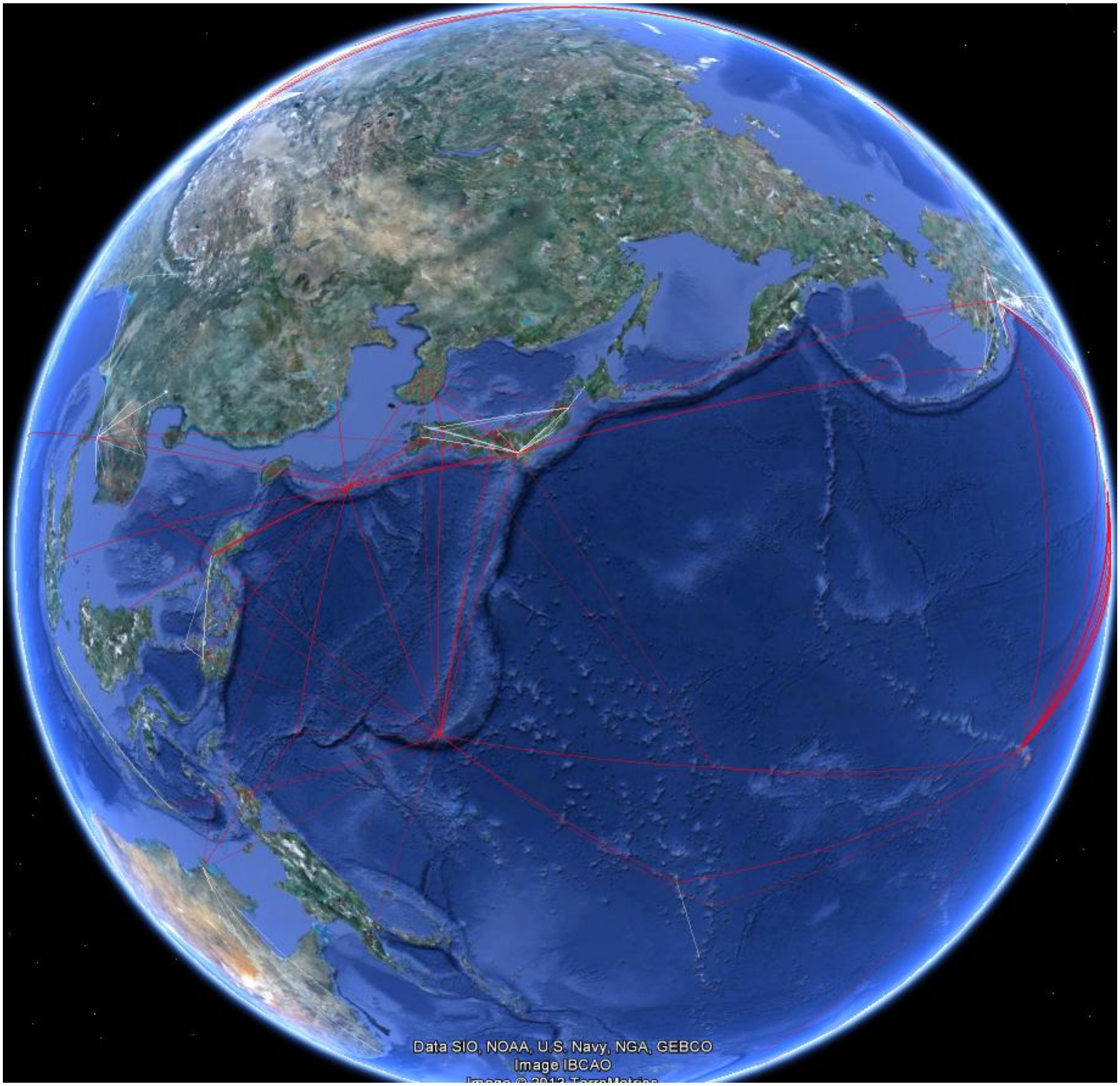


Figure 85. C-130 Flights with Passengers From October 2009 to March 2013. Pacific

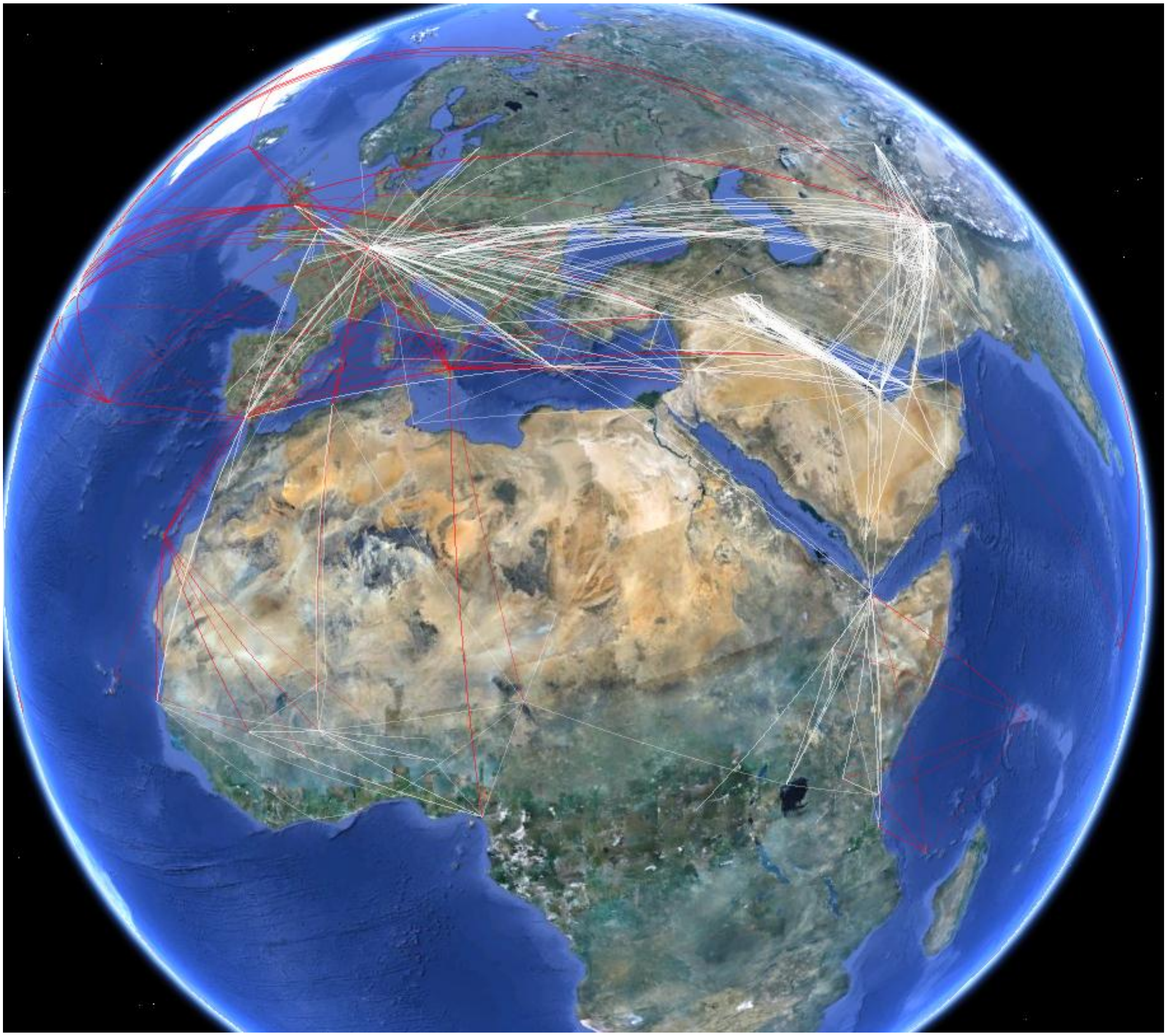


Figure 86. C-130 Flights with Passengers From October 2009 to March 2013. Southwest Asia

KC-10

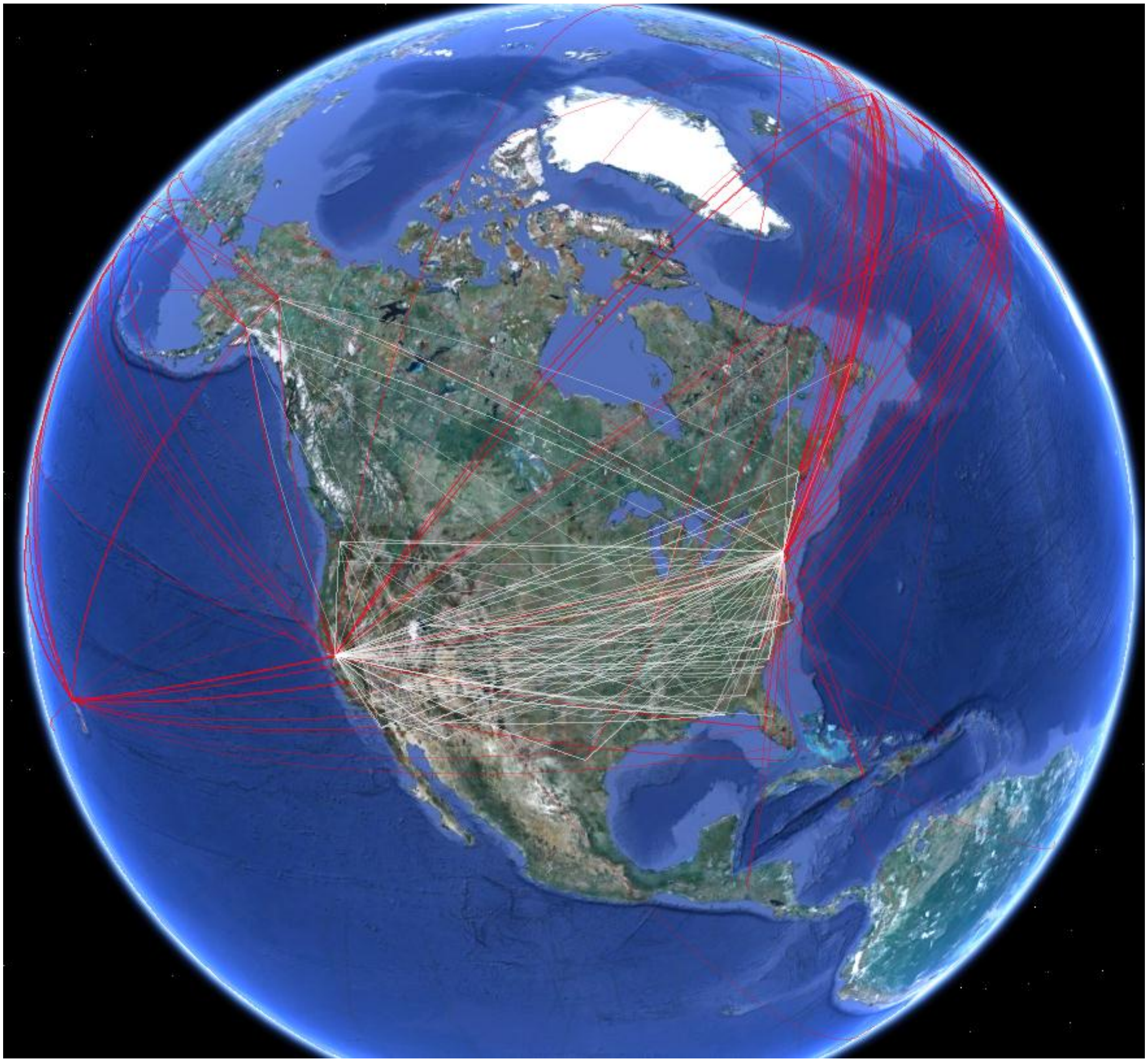


Figure 87. KC-10 Flights with Passengers From October 2009 to March 2013. Americas

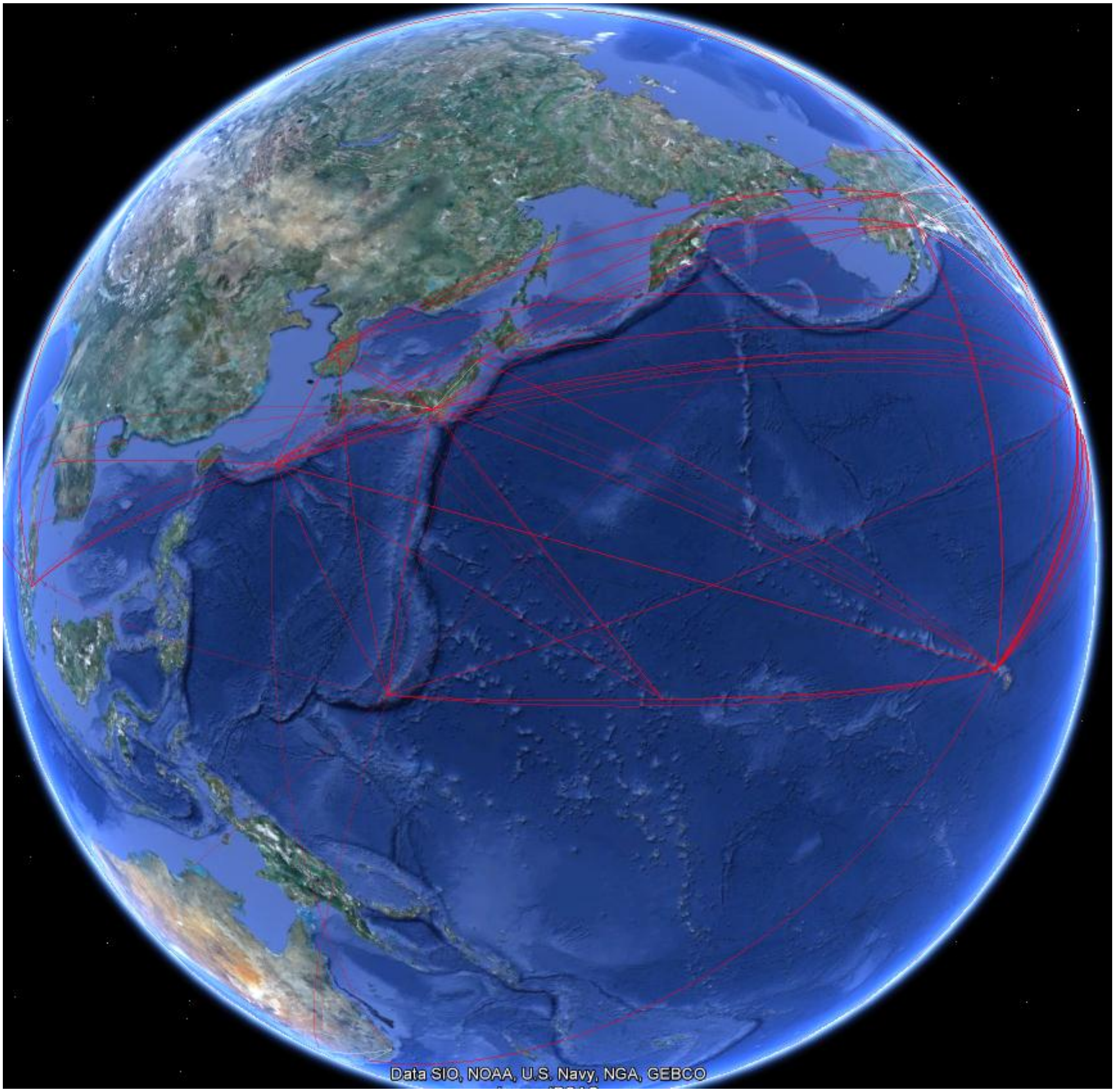


Figure 88. KC-10 Flights with Passengers From October 2009 to March 2013. Pacific

Figure 89. KC-10 Flights with Passengers From October 2009 to March 2013. Southwest Asia

KC-135

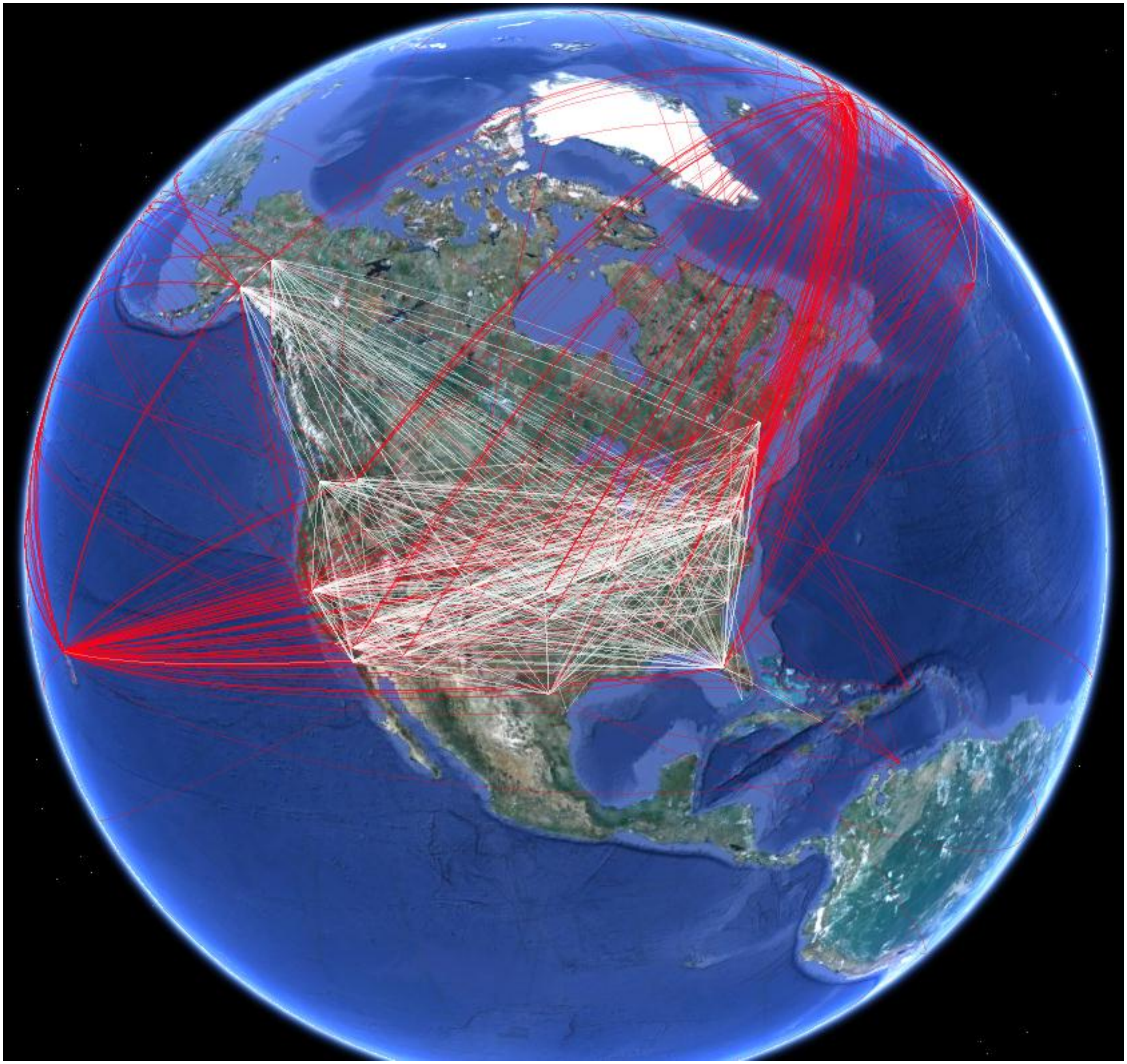


Figure 90. KC-135 Flights with Passengers From October 2009 to March 2013. Americas

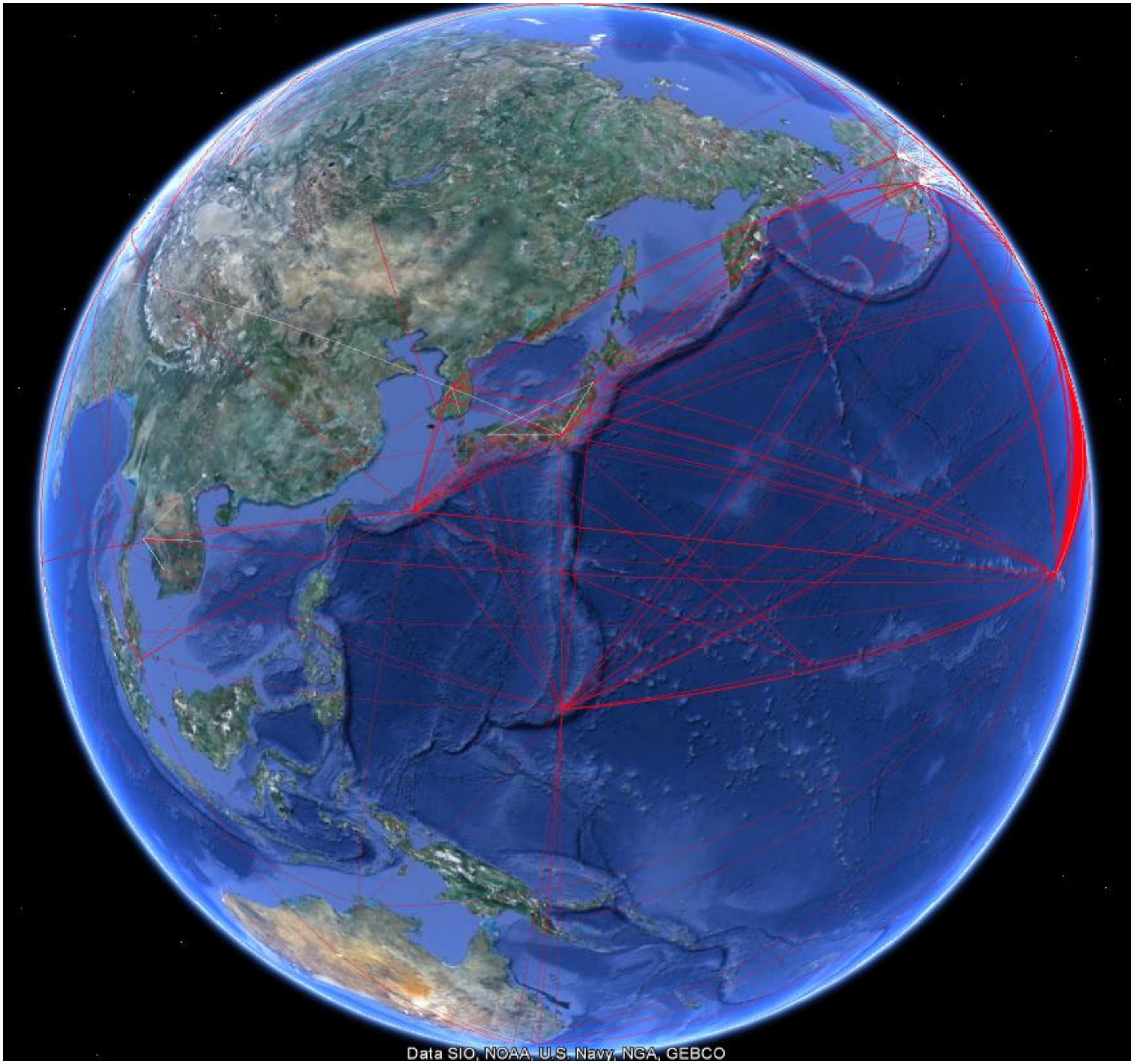


Figure 91. KC-135 Flights with Passengers From October 2009 to March 2013. Pacific

Figure 92. KC-135 Flights with Passengers From October 2009 to March 2013. Southwest Asia

Appendix E: AFIT Human Subjects Exemption Approval

DEPARTMENT OF THE AIR FORCE
AIR FORCE INSTITUTE OF TECHNOLOGY
WRIGHT-PATTERSON AIR FORCE BASE OHIO

14 Dec 2012

MEMORANDUM FOR DR ALAN HEMINGER

FROM: William A. Cunningham, Ph.D.
AFIT IRB Research Reviewer
2950 Hobson Way
Wright-Patterson AFB, OH 45433-7765

SUBJECT: Approval for exemption request from human experimentation requirements (32 CFR 219, DoDD 3216.2 and AFI 40-402) for student research on the utility of carrying large life rafts on the C-130, KC-10, KC-135, C-5 and C-17 cargo aircraft.

1. Your request was based on the Code of Federal Regulations, title 32, part 219, section 101, paragraph (b) (2) Research activities that involve the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior unless: (i) Information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) Any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, or reputation.

2. Your study qualifies for this exemption because you are not collecting sensitive data, which could reasonably damage the subjects' financial standing, employability, or reputation. Further, the demographic data you are collecting and the way that you plan to report it cannot realistically be expected to map a given response to a specific subject.

3. This determination pertains only to the Federal, Department of Defense, and Air Force regulations that govern the use of human subjects in research. Further, if a subject's future response reasonably places them at risk of criminal or civil liability or is damaging to their financial standing, employability, or reputation, you are required to file an adverse event report with this office immediately.

WILLIAM A. CUNNINGHAM, PH.D.
AFIT Research Reviewer

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Vita

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November 2012

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2012 - Present	IDE Student, ASAM; USAF Expeditionary Center, JB McGuire-Dix-Lakehurst NJ
2011 - 2012	Assistant Director of Operations, C-130 Operations Support Squadron; 317 AG, Dyess AFB TX
2009 - 2011	Director of Staff C-130H/E Instructor Pilot, 317th Airlift Group, Dyess AFB TX
2007 - 2009	AFSO 21 Chief C-130 H/E Aircraft Commander, 317th Airlift Group, Dyess AFB TX
2006 - 2009	READINESS FLT/CC; KC-135R/T Instructor Pilot 912 ARS, Grand Forks AFB, ND
2005 - 2006	Assistant Flight CC, KC-135R/T Instructor Pilot, 912 ARS, Grand Forks AFB, ND
2004 - 2005	Life Support Officer, KC-135R/T Aircraft Commander, 912 ARS; Grand Forks AFB, ND
2002 - 2004	Executive Officer/Awards Officer, KC-135R/T Pilot; 912 ARS, Grand Forks AFB, ND
2000 - 2002	Student Pilot, Undergraduate Pilot Training; Vance AFB OK

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Air Force Commendation Medal
Air Medal (6 OLC)
Aerial Achievement Medal (1 OLC)
Air Force Achievement Medal

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14. ABSTRACT Often times, onboard safety equipment is overlooked when considering weight-reduction strategies because these items are perceived to be essential for saving lives or reducing casualties in the event of an emergency. However, some legacy items may no longer be necessary or even practical because circumstances have changed; thereby diminishing their usefulness. Therefore, reevaluating past decisions regarding safety equipment could uncover opportunities for cuts. The focus of this paper is to analyze the need for large life rafts on the C-5, C-17, C-130, KC-10 and KC-135.			
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